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THE STUDENT'S GUIDE

TO THE

LOCOMOTIVE ENGINE:

BEING

A Description

OF

THE DIFFERENT MODES OF CONSTRUCTING LOCOMOTIVES, DETAILS OF THEIR COMPONENT PARTS, AND THE NATURE OF THEIR EMPLOYMENT.

WITH

OBSERVATIONS ON THE MANAGEMENT OF LOCOMOTIVES.

ILLUSTRATED BY SEVENTY-TWO COPPER-PLATE ENGRAVINGS.

LONDON:
JOHN WILLIAMS AND CO.
141, STRAND, (LATE CADELL'S.)
1849.

ADVERTISEMENT.

THIS Introduction to the Locomotive Steam Engine consists principally of a Translation from the French, from the works of authors of high reputation.* The subject being so important and valuable, the Publishers deem it unnecessary to offer any further apology, than that they trust it will supply the wants of Students requiring a knowledge of this highly interesting specimen of modern science and mechanical ingenuity.

* Messrs. E. Flachat and J. Petiet, Civil Engineers.

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THE STUDENT'S GUIDE

TO THE

LOCOMOTIVE ENGINE.

CHAPTER I.

GENERAL OBSERVATIONS ON LOCOMOTIVE ENGINES.

1. *A short Description of a Locomotive Engine.*—A locomotive engine is a steam engine with two cylinders, formed on the high-pressure principle, without a condenser. The motion of the pistons is caused by the introduction of steam into the cylinders and its alternate escape, which is transmitted by means of connecting rods to an axle, furnished with two cranks. The alternating motion of the pistons causes this axle to turn round, and two wheels of large diameter are attached to it, which likewise partake of the rotative movement, and thereby displace or carry the engine along.

The boilers of locomotive engines are constructed in a peculiar manner; the fire being inclosed in a box having a double casing, with a body of water between. The air enters between the grate-bars. The smoke, flame, and gas, produced by the combustion of the fuel pass through, in their way to the chimney, a great number of tubes, which are situated in the cylindric part of the boiler, and extend from the fire-box to the smoke-box, and they are surrounded by water. These tubes, being of very small diameter, would not pass off the flame and gas with sufficient rapidity if they were not urged

by a powerful draught; this is also rendered necessary to overcome the friction, and the resistance offered by the cold air within them.

2. *Of the Draught.*—The draught is employed to produce a fresh supply of air in the fire-grate, and thereby supply the oxygen necessary for the combustion of the coke; it is accomplished by allowing the waste-steam to escape at a tolerably high pressure, after it has fulfilled its office in the cylinders, and imparted to the pistons the alternative movement which is converted into a rotative motion for the wheels. This steam is conveyed from the cylinders to the chimney by a pipe, the upper end of which is contracted for the purpose of confining it, and checking its too rapid escape. It passes off at regular intervals, according to the velocity of the engine, and the force of each puff depends upon the pressure of the steam. The velocity of the steam in the blast-pipe is equal to that due to the initial pressure of the steam, whatever may be the size of the mouth of egress; but the pressure is at once reduced if the size of the orifice* be considerable—if, on the contrary, it is made small, the pressure is less affected. The reduction of the orifice, therefore, increases the length of time which the steam takes to escape, but not its initial speed; and it results from this augmentation of time, that when the engine is working with great velocity, and the intervals of escape are very short, the pressure of the waste steam is, to a certain extent, almost constantly exerted in an opposite direction to the motion of the pistons, and consequently opposes the progress of the engine.

The great speed with which the steam escapes in the chimney imparts to the air around it a corresponding velocity; and this air can only be replaced by a current passing from the grate through the fire and tubes. The draught is thus excited or produced by suction,† instead of being effected by means of blowing.‡

* *i. e.* of the orifice of the blast-pipe.

† "Aspiration." "Insufflation."

We should observe that the contraction of the blast-pipe at its upper extremity, being for the purpose of checking the escape of the steam, and prolonging the time of its engagement, a continued pressure of waste steam is consequently the result, which should be regulated by proper rules or laws, as it ought not to exceed more than is necessary. This pressure is therefore an obstacle to the progress of the engine, in consequence of the draught invariably having the effect of absorbing a notable part of the power of the engine. Its influence, however, is not felt when moving at a slow velocity, on account of the intervals being longer, which gives more time for the steam to escape; but when the speed is great, the piston-strokes are so rapid that the pressure of steam in the blast-pipe is almost continuous. This pressure, consequently, forms a resistance to the motion of the piston almost equal to the power which impels it.* We have frequently observed that the greatest speed which a locomotive ordinarily attains is from five-eighths to rather more than three-quarters of a mile per minute, when the reduction of force arising from the velocity of the steam upon entering the cylinders, and the resistance it experiences in passing out of the blast-pipe, approach towards an equilibrium with the power of the engine. This is both caused by the resistance of the work, and the difficulty which the steam finds in escaping.

Considering the great difference between the power and the resistance, when a locomotive engine first starts with a train, one would be inclined to expect that the accelerating force would *impart* to the train a much greater speed than what it really *attains;* for it is known that the principal resistance which has to be overcome—viz., the co-efficient of the friction of the train on the rails—is not increased by the speed. Therefore the resistance of the air on the one part, and of the spent

* The number of puffs, or steam-escapements, per second, at a rate of rather more than thirty-seven miles an hour, and with wheels five feet three inches in diameter, amount to about 13·2, and the number of revolutions are about 12,000 per hour, or 3·3 per second.

steam on the other, must increase very rapidly with the speed, since the acceleration of the steam is so soon overcome from the effect of these two forces, aided by the increase of the general resistance of the engine. These considerations satisfactorily account for the first stroke of the piston being so very powerful, since, it being at that moment motionless, without any velocity whatever, the steam consequently acts in the cylinders with the same elastic force that it possessed when in the boiler.

The draught is, nevertheless, the means of producing sufficent steam for a rapid transit of the engine: it draws the air into the fire-grate, which is equally necessary with the coke, the combustion of which produces the caloric, whereby the water is converted into steam.

A locomotive engine is formed of several distinct parts, which the conductor should be well acquainted with.

3. *Of the Boiler.*—The boiler is the most important part of the engine. There is a fire-box connected with it, the bottom of which supports the grate-bars, and the four sides are formed double, in such a manner as to allow of a space of $2\frac{1}{2}$ to 4 inches between them, which is occupied by water; the fire-box is therefore surrounded by that element. It is very important to preserve a sufficient width of water space, otherwise the velocity of the steam at this part of the boiler would prevent the water being replaced with sufficient rapidity, the great heat to which the fire-box is exposed producing steam of very great force; the walls, also, from not being sufficiently cooled by the water, would acquire a high degree of temperature, which would likewise promote the formation of incrustations—the space would consequently become filled up, and the casing soon destroyed from the action of the fire. This serious inconvenience has occurred in boilers where the water-space has been made 2 or $2\frac{1}{2}$ inches. The top of the fire-box is strengthened by pieces of iron, that the force of the steam may not rupture it; and the whole of the flat portions of the boiler, being unable to resist the pres-

sure of the steam within, are also strongly secured together by bolts to prevent their giving way; but this is unnecessary with the cylindric portion of the boiler, which resists the pressure without the slightest tendency to rupture. This part is traversed by 100 to 150 brass tubes, through which the flame and the gas produced from the fuel escape—also the unconsumed air from the fire, as previously stated. The extremities of the tubes are secured to the plates at each end of the boiler.

Considering the complication of this casing, one can readily conceive the great play of expansion and contraction produced by the rise and fall of the temperature, and how much the action of such powerful forces tends to wear it out, and to occasion shocks which the several surfaces exposed to the pressure of the steam are unequal to withstand, their form being unfavourable to it; thus, the flat parts become the soonest deranged. Another circumstance which increases these defects arises from the two extreme parts of the boiler being secured together, partly by the frame and partly by the rails or cross-pieces. The latter are attached to the lining of the fire-box at one end, and to the smoke-box at the other, and are kept cool by the air, and, therefore, are not subjected to those alternate changes which the body of the boiler undergoes. As long as they remain fixed in their original position, they offer resistance to the play of the other parts, but when at length they become unfastened, they afford a passage of escape to the water of the boiler. This great defect might be easily remedied by the manufacturer, there being no necessity for securing the cross-pieces to the fire-box in so strong a manner, since they are not intended to fasten the back part of the boiler to the front. We must conclude, from all these forces acting against each other, that locomotive engines possess some degree of elasticity in their several joinings and fastenings, although difficult to be perceived, and which, so far from impeding their progress, actually renders it, after a time, more easy than before.

When the several parts of an engine are constructed of unequal proportions, the weaker parts yield to the stronger, and therefore suffer: the manufacturer should direct his attention to those forms which will unite sufficient strength with the requisite lightness, in order to acquire the proper elasticity throughout the whole contrivance.

The fire-box supports the grate, as we have before observed, the bars being moveable, that the fire may be more readily removed when occasion requires it.

The surface of the grate varies from 236 inches to about 393 inches. The last dimensions are generally applied now, as they render the motion of the engine more easy and ensure regularity in the transmission of the trains, even with heavy loads, or with ordinary trains upon steep inclines. They also produce an economy in fuel, the driver being enabled to regulate the draught according to the supply of steam that may be required, by means of the damper which was invented by Mr. Stephenson. The economy attending great fires arises from the heat being proportionately much more regular than with small ones, although this is partly absorbed by the loss of coke falling between the grate-bars. The large grates contain nearly half as much more fuel than the smaller ones. It is possible that the rise of temperature, produced by the burning of such a large body of coke, exerts an unfavourable influence on the flat sides of the fire-box, the dimensions of which are so considerable. Experience alone can determine which packs the best; we are more inclined to recommend an increase in the depth of the fire-box than in the surface of the grate. It is probable that an increase in the depth of the grate, combined with the employment of a fuel so little inclined to cake as coke, would be found more advantageous than enlarging its surface, since the passage of the air through a great thickness of coke would raise a large quantity of it to the temperature necessary for its combustion, instead of passing through the fire unconsumed, as it does, when filled with too large pieces or laid too thin.

We have only to remark, in addition to our description of the boilers of locomotive engines, that the casing should, at the same time, possess great strength and pliability: thus, where a very powerful draught is created from a rapid succession of *puffs* of high-pressure steam, the heat of the fire gives a high temperature to the several surfaces of the fire-box and tubes, and steam of extraordinary power is generated; but if the door of the fire-box be opened, a large quantity of cold air is admitted, or, if the pumps be held open too long, the air introduces itself into the boiler, and instantly checks the generation of steam; the pressure is consequently diminished, and at length becomes unequal to a rapid transit of the engine.

In locomotive, as in stationary engines, the whole of the parts in contact with fuel, flame, and hot air, should be covered with water: numerous inconveniences arise from neglecting this precaution, the burning of the uncovered parts being the most general. It also renders them more likely to rupture, since those portions which are burnt from being in contact with the flame lose their strength, and yield to the pressure of the steam. But the most serious consequences occur if the uncovered portions are allowed to become red hot, and a quantity of water sufficient to cover them is suddenly let into the boiler; the production of steam is so rapid, that it becomes too considerable to be wholly carried off by the slides and valves, and an explosion consequently follows. We are not, however, aware of a single instance of an accident of this kind having occurred with a locomotive engine, as the drivers take care to throw away the fire, or diminish its intensity, before filling the boilers, and thus give the parts which are covered with water time to cool.

If the level of the water in the boiler should happen to be below the top of the fire-box at the time of departure of the train, and the parts uncovered should become red-hot, it would not fail to occur from the phenomena before described; and, furthermore, from the artificial rise in the level of the water. As the production of steam increased, the red parts would be

instantly covered with water, and cause the generation of a body of steam of greater pressure than the valves could carry off. This kind of accident is, however, almost impossible, as the water in the boiler is, on the contrary, always in excess at the time of departure. Another provision for the protection of boilers consists in making the safety-valves capable of letting off all the steam that can be produced, and in loading them with a pressure much less than what the boiler can support. The boilers of locomotive engines are able to support a pressure of fifteen atmospheres, *in a cold state*, without alteration, which is the lawful and customary proof. When in a heated state, the pressure seldom equals seven atmospheres. It should not in general be more than five atmospheres during the transit, *inclusive of the atmospheric pressure*, and four atmospheres when stationary.

Another very essential point for the preservation of boilers is to prevent the formation of deposits. These arise from the calcareous matter disengaged from the water when it is converted into steam, and which is not wholly carried away with it, but an earthy matter is left, which is constantly increasing in bulk. These incrustations become fixed principally on those parts where the greater portion of the steam is generated; and, as they acquire thickness, it results that less steam is produced, from their being bad conductors of heat: the metal upon which they are fixed is heated to a much higher degree than the other parts, as it is not cooled by immediate contact with the water. This rise in the temperature of the metal increases the action of dilatation, and renders it less able to resist the pressure; it also has the effect of burning it: the boiler, therefore, requires to be often cleaned, which operation we shall describe hereafter.

There are several ways of avoiding incrustation, one of which consists of placing plastic clay in the boilers to prevent the deposit hardening; another, of putting some colourable substance into the tender, such as the chips or shavings of logwood, wrapped in a cloth or placed in a willow basket; the

water of the tender, being often heated, will mix with a sufficient quantity of dye to prevent the deposit sticking.

This incrustation is the most powerful destroyer of locomotive engines, and it is of the greatest importance to find some means of getting rid of it.

4. *Of the Phenomena connected with the Generation of Steam.*—Some of the phenomena which take place in the generation of steam are very necessary to be known. When the grate throws out so much heat, that the escape of the steam from the cylinder is sufficiently strong to cause a powerful draught, then the power of generating steam attains its maximum; at which instant, the bulk of the water in the boiler rises artificially to the height of two to three inches. This is caused by the rapid passage of the particles of steam through the water, which has the effect of increasing its volume. As soon as the regulator is shut, the emission of steam is suspended and the water takes its natural level—also when cold water is injected into the boiler, which, in proportion as it is introduced, condenses those particles of steam with which it comes in contact in the mass of heated water, and thus restores the density it had lost. It results, that the level of the water remains constantly at the same mark as long as it continues to be fed, and that the introduction of water is only perceivable by the reduction of the pressure. The artificial rise of the water is also much greater towards the steam entrance than at the other parts of the boiler; it therefore follows, that the phenomenon is strongly exhibited in engines in which the gauge-tubes are placed near the steam entrance, and when the water-space of the double casing enclosing the fire-box is formed too narrow.

Another fact equally important to be known is the disposition of all locomotive engines, more or less, to carry away a quantity of water into the cylinders with the steam. This inconvenience arises from various causes. It may arise from the manufacturer forming the regulator with too great an opening, which diminishes the pressure, and imparts a considerable

degree of ardour to the ebullition, so that the several particles forming the water rise and pass out with the steam; or, from filling the boiler so full that the water rises up beneath the dome over the steam entrance, and is conveyed into the steam entrance-pipe with the same velocity as the steam: lastly, it may occur from greasy matters having been introduced, and got spread over the interior sides of the boiler, which, becoming mixed with the water, give it a property analogous to that of milk when submitted to an ebullition, and the quantity of water engaged by the steam in this case is very considerable.

The causes which produce priming depend upon the construction of the engine: it either results from the small diameter of the dome—its want of height, or the space reserved for steam above the surface of the water being too small, which causes the steam to acquire too great a velocity, whereby it has not time to drain; or the dome being placed over the fire-box, which is too often the case—that is to say, it is placed at that part where the evaporisation is greatest, and the particles of water are in the strongest agitation.

The way to separate the steam from these particles of water, before its departure from the boiler, in each of the cases before stated, is to shut the regulator, and subsequently to open it by degrees when the water is only bubbling, which has the effect of stopping the current of the steam, and rendering its pressure in the boiler greater than it was before, and comparatively less in the steam-pipe leading to the cylinders; the quantity of steam let off by the regulator also ceases to equal the total production of the boiler; the power of the ebullition is arrested: the pressure of the steam above the surface of the water being now equal to that of the steam generated beneath the surface, the latter is consequently prevented rising, and thus the steam has time to disembarrass itself of the water in suspension previous to entering the cylinders.

By reducing the aperture of the regulator, the velocity of the steam passing to the cylinder is increased, arising from the difference between the pressure in the boiler and the

pressure in the steam-pipes to the cylinders. The power of the engine would be diminished, if an engine were worked with greater or smaller power, accordingly as the regulator was more or less opened; but this law is far from being constant in practice, and a driver would be much deceived if, with a view of obtaining the highest speed of an engine, and the greatest amount of traction with a considerable load, he opened the regulator to the utmost extent. Experience proves that, in this case, there is an absorption of steam which is not in proportion with the maximum of useful effect. The quantity of water in the boiler also becomes diminished after a short time, if the regulator is kept entirely open, to such an extent, that the feeding becomes very difficult without cooling the boiler, so that the amount of steam and the power are rendered insufficient to propel the engine. This arises from the quantity of water that the steam carries with it, and the mode of constructing the boiler, and in the difficulty, nay, almost incompetency, of the engine to furnish a supply of steam equal to its rapid ejection from the cylinders at high velocities. The generation of steam at the moment of starting an engine, produced by the passage of the flame through the tubes, increases the volume of the water, and mechanically diminishes its density, when the level of the water consequently rises in the boiler. Therefore, unless the whole of the steam passed out without the water which it held in suspension, on account of the latter being arrested by a pressure in the boiler superior to the force in the steam-pipe, then this water would be carried by the current of the steam, would continue to rise with it, and be drawn into the cylinder, and from thence pass out into the air. The aperture of the regulator should therefore be diminished in such a proportion, that the pressure in the boiler shall exceed that in the steam-pipe. The steam drains better when under the influence of this pressure, doubtless from a kind of attraction arising from the difference in the density of water and steam, the effects of which are felt more than usual on these occa-

sions, and the steam escapes from the water held in suspension solely by reason of the velocity of its ascent. The proof that the artificial rise of the water in the boiler is produced by none other than the mechanical action of the rise of steam in the pipes is, that when the regulator is shut, the water immediately falls to its proper level.

This fall in the level of the water in the boiler, which occurs every time the aperture of departure is closed or partially reduced, depends on the physical law of the generation of steam under different pressures.

Water, in common with all other liquids, is in its natural state of union when at certain temperatures and at certain pressures only; thus, the conversion of liquids into steam is influenced by these two circumstances—viz., the temperature and the pressure. If the pressure exerted on a liquid be reduced, the temperature remaining the same, a point will be arrived at when ebullition will occur—thus, water will boil at the temperature of 66°,* by reducing the pressure on its surface to 0·25 of an atmosphere. If, on the other hand, we increase the temperature and leave the pressure the same, we shall still be able to convert the water into steam; for water, when under the influence of the common atmospheric pressure, does not change its physical state until it reaches 100°; and if the pressure is increased to two atmospheres, evaporation will not take place until it is 121° 55.* It is on the relation existing between the temperature and the pressure, rather than the generation of steam, that the fall of the level of the water in the boiler depends, as, when the mouth of egression is contracted, or any other cause, the pressure on the liquid is increased: and, moreover, when the temperature of the water does not immediately rise to a corresponding degree to the pressure, supposing the latter to be suddenly increased, the evaporation actually ceases for a certain period, and is only renewed upon the transmission of the requisite quantity of heat from the fire-grate and tubes.

* Of the centigrade thermometer.

We can also readily account for the rise of the level of the water in the boiler, from the circumstance of its ebullition only; indeed, the presence of the steam-bubbles must necessarily have the effect of displacing the water, and causing it to occupy a bulk of much greater volume.

5. *Of the Economy of Fuel.*—We have before observed, that the dimensions of the fire-grates of new engines are made much larger than those constructed previously, from which a much greater force of evaporation has resulted, the quantity of fuel which they contain being considerable, and the surface of the furnace so much extended.

The manufacturers at length thought proper to proportion the increase of the fire to that of the cylinders; but the power of the draught, resulting from a greater quantity of steam being discharged up the chimney, so increased the effects of the mass in combustion, that the generation of steam quite exceeded the ordinary wants of the engine.

This circumstance leads us to enter into some considerations on the economy of fuel employed in the working of locomotive engines.

The small engines, furnished with 11 to 12-inch cylinders, and with grates from 256 to 275 inches square, do not generate more steam than can be delivered at the cylinders with a velocity of 22 miles an hour, with a mean pressure of three atmospheres, which is sufficient to impel ordinary trains; indeed, a less power is often sufficient, when the engine consequently goes faster.

In the new engines of larger dimensions, the surface of the furnace having been increased in a greater proportion than the cylinders, they are able to maintain the speed of 22 miles, by keeping the steam which feeds the cylinders at a pressure of three and a half atmospheres, which is requisite, to enable them to work the ordinary trains upon grades of 1 in 200; but the engines of this class running upon the St. Germain's railway generate steam in much too great quantities—hence the necessity of regulating the fuel.

The means employed by the engine-drivers of the present time in reducing the consumption of fuel, consists in taking care not to overcharge the grate, and in opening the door of the fire-box during the running of the engine. These methods are attended with serious consequences. When the grate has but little fuel in it, the least addition cools or damps the fire; the loss of coke is also very great, because the grate partakes of the shocks to which the engine is subjected, and the coke receives a movement similar to that which it would be subjected to from motion in a sieve; the coke, also, being light in itself, is drawn up by the draught, and, from want of sufficient thickness or substance, it is danced about on the grate, which has the effect of bringing the smaller pieces to the bottom part, when they fall between the bars and are lost on the road.

Opening the door of the fire-box for the purpose of slackening the fire has yet worse consequences, as it allows a large quantity of cold air to enter between the bars, which has the effect of causing a contraction in this part of the boiler; the degree of expansion of the ferrules differing from that of the fire-box and tubes, the action upon the fire-plates, the tubes, and the ferrules being also in different directions, a sensible alteration in the joinings and the *passages* through the tubes is therefore very generally the result.

The passages are heated more or less, accordingly as the water yields deposit, as before stated; and as the calcareous portions collect between the joints, from being momentarily loosened by the expansive motion, they are prevented drawing together again, and thus cause a greater heat to the water-passages, at the joints of the tubes, than they would otherwise be subjected to. The joints of the tubes are sometimes drawn close again by employing good water, which is probably owing to the calcareous matter which held them open being gradually washed and carried away.

The inconvenience of these two methods of regulating the combustion of fuel, together with the negligence of the engine-

drivers in applying them, produces this effect. The generation of steam in the engines is never properly regulated; it is very powerful when the fire is full of coke in a burning state—and it is barely sufficient when the fire is but little packed, or after cold coke has been put on. The consequence is almost inevitable, that the driver is obliged to employ the fuel in excess, and, consequently, to generate more steam than is required along the greater part of the line, which escapes at the safety valves—that he is deprived of a means of regulating the fire after the requisite quantity of steam has been generated, and he is unable to manage the fire when it becomes too fierce.

This inconvenience causes a waste as considerable as it is useless, which is very serious with engines having 12-inch cylinders, when they do not carry a full load, which is frequently the case. It is therefore much greater with engines having large grates, when it becomes essential to introduce some means of modifying the draught, which the engine-driver may avail himself of, in order to regulate the consumption of fuel and proportion it to the work that is to be done; *i. e.* according to the steam that is required to be generated.

6. *Of the Dampers employed to regulate the Draught.*—One of the means employed of regulating the draught consists of placing a disc valve at the extremity of the blast-pipe, which was the invention of Stephenson. This valve is open in the middle, by which it does not offer any obstacle to the passage of the steam; but it can be made to close the passage whence the flame or gas produced by the fuel issues, when required. This damper is managed by the engine-driver by means of a lever rod.

This valve is also useful for another purpose. Thus, when the men extinguish the fire of the engine after it has finished work, the grate being done with and removed, the air enters at this part with great freedom, the heat of the engine maintaining a very strong draught. Now the effect of this passage

of cold air is detrimental to the boiler, for the reasons before stated; therefore, if Stephenson's damper be fitted in the chimney, and care be taken to shut it close on these occasions, the current of air would be checked, and an excellent effect would result from it. Another plan might be practised, in connexion with the above, with great advantage—viz., a second pipe might be placed at the commencement of the blast-pipe, opening below the smoke-box by a cock of large size, which could also be managed by the engine-man by means of a lever-rod, by which a certain quantity of the waste steam would be let off, and the quantity passing out through the upper end of the blast-pipe would be reduced; the draught would thus be diminished, or might be altogether suppressed. This plan would have a great advantage over the other, through increasing the amount of area for the purposes of escapement; by opening this cock, the pressure that the steam is subjected to in passing out through the small orifice of escape would be reduced, and thus the power of the engine would be increased. We, therefore, consider it our duty to recommend its adoption. Experience has already pointed out something analogous to what we here advise. One of the locomotive engines constructed by Bury, and employed upon the St. Germain railroad, having an excessive evaporating power, the conductor was induced to work it with the cleansing cock, connected with the blast-pipe, kept constantly open, which has rendered the draught more moderate, and consequently effected a certain economy of fuel. The power of regulating the opening of this cock, and of increasing it almost to the extinction of the draught, when circumstances may render it necessary, is all that is required to complete the contrivance.

7. *Of Explosions.*—We have few remarks to make on the subject of explosions connected with locomotive engines. Accidents of this kind are wholly attributable to the wilfulness of the engine-driver, or a want of care on his part. His first duty is to notice that the safety-valves do not emit steam exceeding a pressure of five atmospheres at the utmost. An

engine is not properly regulated, if the ordinary safety valve alone emits the steam when the latter is at the above pressure; the lock-up safety valve should be equally affected.

It is probably from these explosions being so rare, that the cause of them has been a question up to the present time; we can give none other than that they are owing to the imprudence of the engine-drivers, from their endeavours to raise the power too high, and thus impeding the escape at the safety valves: perhaps this imprudence may be combined with a bad system of closing and bolting the iron plates, and defectiveness in the large interior iron bolts of the front plate. We do not, however, mean to affirm this, but only mention it to our readers, inasmuch as we know that the *joinings* and arrangement of the plates of some boilers are much less skilfully contrived to resist internal pressure than others.

Explosions are very dangerous to the engine-men, because the front plate is the first to yield to the pressure of the steam, the surface of which is of considerable dimension; the passengers, however, are not subjected to the least danger, but are merely brought to a stand, by the breakage.

The engine-men employed on the Paris and St. Germain's railway are not allowed to load the *ordinary* safety-valve beyond five atmospheres, which example should be generally followed. The lock-up safety-valves should be out of their power, and under the care of the superintendent-in-chief of the train. By taking these precautions, explosion may be rendered impossible.

One more observation will be sufficient to prove to mechanics the uselessness, generally speaking, of increasing the pressure, and of tightening the safety valves. When they thus increase the pressure of the steam in the boiler, the engine simply acquires the power of propelling a heavier train, but it has not any sensible effect upon the speed. They should, therefore, remember that they do not derive any advantage from committing this very great offence. As the steam in the cylinders acts at a less pressure than that in the

boiler, of what use is it to increase the latter, when, by opening the regulator a little more, sufficient additional strength is obtained in the cylinders? The most essential thing for the speed is the generation of a large quantity of steam at once, and of the requisite force—sufficient for the discharge of a great number of strokes, and not steam generated under a greater pressure than there is any occasion for. Let the engine-driver, therefore, employ himself solely with directing the fire and feeding the boiler in a proper manner; and it is highly important that he should see the necessity for this.

8. *Of the Apparatus connected with the Distribution of the Steam and Regulators.*—After the requisite preparations for the generation of steam, follow those necessary for its distribution; that is to say, those required to convey it from the boiler to the cylinders, where it employs its power upon the pistons, and thus produces the motion whereby the engine is worked: it is made available again in its passage from the cylinders to the chimney, since its escapement produces the draught. These pipes of distribution have some important variations from the apparatus employed for similar purposes in stationary engines.

The steam entrance, or the aperture by which the steam is introduced into the pipes of distribution, is situated in the interior of the boiler, and opens at the upper part of the dome surmounting it. The object of the dome is to carry the steam as high as possible, that the water held in suspension may have time to drain from it. The pipe by which the steam is introduced* is carried along to the extremity of the boiler, and passed through into the smoke-box, where it is divided into two, to supply each of the cylinders. This pipe may be contracted in the interior, by means of an apparatus termed a regulator, which is inserted for the purpose of regulating the transmission of steam to the cylinders; this apparatus will also entirely close the passage of the steam-pipe, if required.

* Steam-pipe.

The steam entrance is placed either at the head of the boiler, above the fire-box, or, otherwise, towards the extremity near the chimney. In the first case, where the pipe traverses the entire length of the boiler, it is attached to the plates at each extremity; and, in order that it may readily yield to the action of expansion, it is furnished with a stuffing-box.

The joints of that portion of the steam-pipe within the boiler should be made with the greatest care, that the water may not gain admittance into the pipe. It is generally formed with a section equal or superior to that of the steam-ports in the passage to the cylinders, and the same as the apertures opened and shut by the regulator.

Regulators are constructed of various forms; but that generally employed consists of two separate discs, one being made moveable; and they are cut in such a manner, that the open parts of one will either correspond with or cross those of the other, so that the steam passage may be left either open or closed.

The moveable disc is secured to the fixed disc by the pressure of the steam, also by a screw and a spring; the spring is rendered necessary, from the steam within the steam-pipe being sometimes of greater pressure than that in the boiler. We shall explain this when the motion of counter-steam is discussed.

Other forms of regulators have also been employed—and the principle of safety-valves has been applied in some cases, and in others the principle of cocks—again, that of slides; those which present the least surface-friction, and in which the apparatus is brought into action upon the least degree of force, are the best, for it is important to counteract the effort required to overcome the pressure of the steam by suitable contrivances, as by equilibrating it by a pressure nearly equal; the friction resulting from the unequal expansion of the several pieces fixed and enclosed within each other should also be reduced as much as possible. Regulators formed with cylindric surfaces exposed to the action of friction possess this

inconvenience in the highest degree. There also appears to be some ground for rejecting regulators which require helixes in the interior of the boiler, upon which the pressure of the steam would act.

It is of the utmost importance that the engine-man should perfectly understand the form of the regulator belonging to his engine, as the degree of opening of the aperture is one of the chief requisites for uniform progression, with finely-constructed engines and those of slight dimensions. If the regulator be opened too much, it lessens the generation of steam in a few moments; and if too little, it diminishes the force of the steam generated by the engine exceedingly, and therefore impedes its progress.

9. *Of the Cylinders, Slide-boxes, and Slides.*—The steam passes along the breeches-piece leading to the cylinders through the slide-boxes, from whence it is distributed alternately upon each side of the piston.

The mode of introducing the steam may be readily comprehended; the bottom of each slide-box is pierced by three holes called *ports;* the two extreme *ports* convey the steam into the interior of the cylinders at their extremities. A sort of cover, called a slide, is placed over them, which is subjected to an alternating motion when at work, and thus leaves each port alternately uncovered; and as the slide-boxes are kept constantly filled with steam, the latter passes through these ports into the cylinders at the moment of each being uncovered. It will therefore be perceived, that the system of introducing steam is very simple. The ejection of the steam from the cylinders remains to be explained: every time that steam enters upon one side of the piston, that which has effected the preceding half-stroke escapes at the third port, which is pierced in the bottom of the slide-box, and is not in communication either with the cylinder or the slide-box, where the steam is lodged, but is separated from these, and is constantly covered with the moveable slide, which covers and uncovers alternately the two other ports: it is furnished with

a pipe at the extremity which leads into the chimney. Now, the moveable cover or slide being hollow, it results from its alternate motion that when it uncovers one of the steam-ports and admits steam into the cylinder, it puts the other steam-port in communication with the waste steam-port situated between them, by means of the cavity beneath it; and the steam admitted into the cylinder, at the preceding *half-stroke* of the piston, by the port then uncovered, enters the interior of the slide, forces itself through the waste steam-port, and thence escapes; therefore the slide-box constantly answers as a passage to conduct the steam into the cylinders, and the cavity within the slide serves only for a passage to convey the steam away from them. The true steam-ports admit steam when they are uncovered, and they alternately convey steam to the waste steam-port when they are covered by the slide; thus, the slide never leaves more than one of the steam-ports uncovered at a time for the passage of the steam, and it covers the other two at the same time, to allow of the waste steam escaping. The force of the steam lodged in the slide-box is therefore employed upon the piston. The waste steam, being put in communication with the atmosphere under the slide, instantly loses its force. The piston is then quickly carried along to the other end by the force of the steam, and the resistance it encounters on the other side is quickly overcome. Now, it is the difference between these two forces which causes the engine to perform its several functions; if these forces were equal, the piston would remain in equilibrio, and without motion. In order that this difference shall be as great as possible, the force of the steam entering the cylinders should not be less than that which exists in the boiler, or the pressure of the steam that passes out of the cylinders greater than the pressure of the atmosphere into which it escapes; but this desideratum is difficult to be attained. The pistons of locomotive engines being impelled with great velocity, the steam is necessarily carried into the ports of introduction with a velocity which is in inverse pro-

portion to the section of the uncovered part (of the port) with the area of the cylinders. This velocity is further affected by the irregularity attending the conversion of a rectilinear motion into a circular one. The latter is accomplished by means of a crank-arm, which follows every movement regularly, and transmits the motion to a rectilinear horizontal rod, the velocity of which is represented by 0.293 for the quarter of the revolution which approaches nearest to the vertical, and by 0.707 for the quarter nearest the horizontal. Thus, the total speed of the piston is composed of a minimum and of a maximum; the minimum takes place when the crank-arm passes above and below the horizon—the maximum, when it performs the quarter of the circle of the passage from one side to the other of the vertical; in other words, the more the direction of the movement of a crank-arm approaches to a parallel with the rectilinear rod which it works, the greater is the speed transmitted to the rod; and the more it moves from a parallel, and approaches the rod by a perpendicular movement, the slower is the motion imparted to the rod.

When the engine works at its greatest speed, or at about 38 miles an hour, or 1093 yards per minute, the size of the wheels being 5 feet 3 inches, and their circumference 16 feet 6 inches, the number of strokes of each of the pistons is about 200 per minute, and of their movements, 400, the length of each being about 1 foot 6 inches, which gives the piston a velocity of 192 yards per minute, or 10 feet per second, instead of about one yard, which is the velocity given to the pistons of stationary engines. The dimensions of the ports are generally 1-10th the area of the piston; the velocity of the steam in the ports would be about 100 feet per second, if they were always entirely open when the piston was moving, which is not the case, the aperture being only fully open during the middle of its course, and at a point where the piston has a speed once and a half as fast as its mean velocity; the velocity of the steam through the ports would therefore be about 165 feet. Taking the contractions, also, into account,

reduces the openings to two-thirds; we thus find that the steam has a mean velocity of 200 to 250 feet per second at the ports. This velocity, although very considerable, does not, however, produce the injurious effect that was at first imagined. The velocity of the waste steam, in passing into the void, is upwards of 1970 feet per second, and its velocity upon escaping into the atmosphere is about 1400 feet, when the absolute pressure of the steam is about two atmospheres.

This velocity is more than 870 feet for an effective pressure of a quarter of an atmosphere, or an absolute pressure of 1 at: 25; indeed, the generating pressure of a velocity of escapement equal to 290 feet does not exceed 1-50th part of the atmosphere alone.

The resistance arising from the steam-ports is, then, perfectly unaffected at high velocities, but if the latter were even considerable, it would not have a troublesome effect; indeed, with a speed of 37 miles an hour, the boiler cannot furnish the cylinders with any other than steam of reduced pressure; therefore, of what consequence is it that this reduction should be partly caused by the ports, instead of being wholly effected by the regulator?

But although we have no loss of force arising from the steam-ports, this is not the case with the waste steam-ports. The force which the steam exerts in its escape always diminishes the useful pressure — and it is very considerable, since the velocity is of necessity very great, in order that the cylinders may be instantly cleared. It is, therefore, necessary that the velocity of 250 feet, although sufficient when continued throughout the stroke, should be considerably increased, in order that it may be enabled to free one side of the cylinder instantly.

In the next place, the steam, after passing out of each of the cylinders, again unites in a pipe, which is contracted at the upper extremity, and presents another impediment to its passage. This peculiarly-formed pipe is employed for the purpose of creating a draught. But the resistance which it produces

is naturally detrimental to the moving power, which may be accounted for as follows:—Suppose that, with a speed of 39 miles, the cylinders are filled with steam of 3 at: 75, which is successively held and dispersed. In calculating the volume of this steam, with successive stops, we should find that it is nearly double that of the cylinder. Taking the total volume of steam supplied, having the section of the blast-pipe, (whose conical shape does not present much contraction,) we arrive at this result, that, supposing the escapement to be incessant, the steam would have a mean velocity of 820 feet, corresponding to a generating pressure of a quarter of an atmosphere. This result shows that this great velocity of escape absorbs a considerable portion of the power of the engine; and if we remember that, at these same velocities, the motive steam must necessarily diminish the pressure—also that the air operates upon, and at length overcomes it, we can easily conceive that there are certain limits to the velocity, which cannot be exceeded with certain engines, even when running without a load. These limits, which were originally from about 39 to 44 miles an hour, have been increased, with engines made more recently, to nearly 53, or even upwards of 60 miles an hour.

10. *Of the Distribution of the Steam by the Eccentrics.* — As we have before stated, the steam introduces itself into the cylinders upon each side of the pistons, and escapes uniformly on the opposite side to which it entered; it exerts a pressure on these pistons, which constitutes the power and the means whereby the engine works. It is necessary to understand how the steam is alternately distributed, so as to impart this backward and forward motion to the pistons, and how it becomes changed into a rotative movement, and forces the engine along. The two pistons are each attached by fixed rods, to guide them in their rectilinear strokes, and by moveable rods, called connecting rods, to an axle furnished with two cranks, set square with each other; this axle is mounted upon two wheels, which are termed the driving wheels, and receive a rotative movement direct from the pistons.

The readiest plan of distributing the steam, at the commencement of the action of the piston, consists of employing the rotative motion of the axle to conduct two eccentrics at the same time with the wheels, which, by their alternating motion, open and close the slides. The eccentrics are placed on the axles of the driving wheels in such a manner, as to disengage the slides from those ports whereby the steam is introduced into the cylinders, and to cover those reserved for its escape, at the commencement of the stroke of the piston; to accomplish which, each eccentric is mounted upon the axle of the wheels square with the crank of the cylinder, the slide of which it conducts. In order to understand perfectly what then transpires, it is necessary to bear in mind that, when a crank transmits motion to a horizontal rod, it impresses the rod with a rapid motion when it passes in a vertical, and with a slow one when it passes in a horizontal direction.

In accordance with this general law, when two crank-arms are mounted on the same axle, and transmit their motion to two rectilinear rods, the motion of each will be different, notwithstanding the cranks are both animated with the same velocity.

Now, the slow movement occurs precisely at the commencement and at the termination of each half-stroke of the piston, since the crank-arm crosses the horizontal at this particular period. Therefore, if the eccentric be mounted square with the crank, the instant that it crosses in a vertical direction, and transmits the greatest amount of velocity to the slide, the crank will be in a horizontal position, and the piston will be taking its slowest movement. The steam is introduced and let off uniformly every time the crank-arm is in a horizontal position—that is to say, every time the piston has finished one stroke and is commencing another—and it is performed with great precision, depending upon the uniform action of the slide. It may be further observed, in the case of one crank being placed on the same axle with another—when one is passing from one side to the other, in making a semi-revolu-

tion, the other is passing from the top to the bottom; or, if each of these cranks transmit a rectilinear motion to a rod, the rod conducted by the first crank conveys a certain motion in one direction, and that conducted by the other conveys the same amount of motion, but distributed in the opposite direction. The results of this uniform principle in the construction of locomotive engines are as follow:—At the instant one of the cranks is in a horizontal position, and the piston at the commencement of its stroke—during the first half (of this stroke) the slide moved by the eccentric, which is in a vertical position, conveys a motion which has the effect of uncovering one of the ports, and by the time the eccentric arrives at the horizon it becomes wholly uncovered. In the second half of the course of the crank, the slide returns to its original position, and the port becomes again covered. The slide is, therefore, always ready to uncover the opposite port at the commencement of the following stroke.

It further results, when the crank is horizontal, that the two steam-ports are shut, the eccentric being then in a vertical position.

Such is the principle of the distribution of steam. We shall not enter into the particulars of the several plans for effecting it at present; but their details, which do not differ essentially from each other, will be found in their proper place. The return motions, from the eccentrics to the slides, are constructed of slight rods, and are therefore readily shifted; yet, as the slides are drawn backwards and forwards under the pressure of the steam, they are subjected to considerable friction; the rods are liable to be strained, and frequently become deranged by the eccentrics, also from the play of the points of the levers, and the several turning-joints being so very elastic. These circumstances of derangement have an important influence, by retarding the slide slightly, which has a powerful effect upon the regularity of the distribution; and since the course of the eccentric is similar to that of the slide, the detention of the action, and the loss of speed occurring in the

return movement from the above causes, show the necessity of the engine-man devoting the greatest attention to this point, and avoiding the evil as much as possible. The distribution of steam may be suspended, whenever required, by means of disengaging levers,* which detach the rods of the eccentrics from the levers which conduct the slides; the same levers are also employed to reverse the movement of the slides* at the time of running, and in such a manner as to render it opposite to the direction the engine is running in.

This reversing the distribution of the steam is employed to stop the engine where other means are found insufficient, in which case the steam-ports on that side where the piston is returning become instantly uncovered, and the steam fills the whole cylinder, and thus opposes the progress of the piston; the latter returns the steam again to the boiler if it should not be arrested. At the same instant, the waste steam-port is covered by the slide, and consequently put in communication with the air, which enters by the blast-pipe, and fills the cylinders, being drawn in by the action of the piston. Thus, the advance of the engine against the steam has the effect of conveying the air into the boiler, and the safety-valves consequently emit steam mixed with air.

11. *Of the Feeding of the Boiler.*— Having described the means of generating steam, and of distributing it in the cylinders, we shall now consider those for renewing the water in the boiler in sufficient quantity, as it becomes absorbed by the work of the engine. There are two pumps employed in effecting this, which are on the lift-and-force principle; the pistons consist of plungers, similar to those employed in ordinary stationary engines. They transmit the water from the tender to the boiler. One of these pumps can deliver a volume of water in the course of about twenty minutes, sufficient to supply the boiler for one hour's run. The quantity of water furnished by the pumps may be properly regulated, and the

* Hand-gear and reversing-handles.

delivery of the same rendered continuous, but the latter is only accomplished in new engines; the boilers of the other engines are sure to be momentarily chilled, either in the operation of feeding it with water, or in replenishing the fire with fuel; but the fires of new engines are not so liable to this, being very powerful.

12. *Of the Machinery, and its Disposal.* — We shall conclude our general observations on locomotive engines, by referring to the disposal of the machinery connected with them. The power of the engine originates in the cylinders, the force produced within them proceeding through the smoke-box in which they are inclosed. This force or power acts in two ways, dependent upon the steam being on one side or the other of the pistons, and imparts to the rods an effort of traction or of pressure accordingly. The whole of this force is exerted upon the cranked axle, wherefore it becomes highly necessary that this axle should be attached to the cylinder-box by very strong framing; the boiler is, for this purpose, placed on a frame, with which it is connected by stays secured by strong bolts. We are of opinion that this connexion is defective in the majority of ordinary engines, since it appears as though the only object was to give support to the frame bearing the weight of the boiler, and not to provide, at the same time, against the forces acting horizontally, arising from the power at work in the cylinders. There are many engines which, after a few months' work, manifest a sensible play, to an experienced eye, between the cylinder-box and the supports of connexion between the boiler and the frame, from this reason. The carriages, or grease-boxes, which receive the gudgeons at the extremity of the axles, and thus support the entire weight of the engines, are situated beneath this frame, the gudgeons turning freely in them.

If these carriages were the only points of resistance to the cylinders, it is probable that not only the supports of the boiler on the frame would soon give way, but the axletree, being only secured at its extremities, would also be subjected

to these vibrations, and the greater part of it so powerfully forced in each direction, horizontally, by the cranks, that they would be soon broken. It is to obviate this that the cylinder-box is attached to the cranked axle by four, or at least three, iron rails. These rails are strongly fastened to the cylinder-box, and each carry a copper collar, in which the cranked axle is enclosed. This collar is capable of moving in a vertical direction, whereby it is enabled to accommodate itself to the play of the springs and countersprings, which frequently have the effect of separating the axletree from the boiler; but the collar is always secured horizontally, being that in which the cranked axle offers the greatest resistance, by means of suspended wedges, which operate similarly to keys, and tighten the carriages against the axletree. The cranked axle is secured in this manner at five or six places respectively, and further attached to the cylinder-box. The attention of the engine-driver should be directed to these rails of attachment, and he should constantly notice that they fulfil their office properly; and in furtherance of which he should tighten them, by heightening the wedges as the carriage of the axletree becomes worn.

The three principal rails, or cross pieces, which we have noticed, are attached just at their extremities, next the axletree, to lugs fastened to the fire-box. It is of consequence that these joints should not be made too stiff, and that a little play be allowed for their extension in cooling, for the reasons before stated—viz., that these rails are not subjected to the same degree of elongation from the effects of expansion as the body of the boiler; and, upon this occurring, the boiler is forced upon the rails, and the joints connecting them with the fire-box consequently become deranged, and give passage to the water situated within the double casing surrounding the fire-box.

In an engine recently constructed, the middle crossing-rail has been omitted, and the collar supporting the cranked axle supported directly by the fire-box. Experience will show the

merits of this new arrangement, which appears to us to be but little warranted.

We have now to observe, that the necessity of reducing the weight of locomotive engines has led to the almost exclusive employment of iron in their construction, from which it results, that the whole of the several pieces in friction against each other, from the effects of rotative or rectilinear movement and the sliding of one surface upon another, are proportionately weaker than those of ordinary stationary engines, the castings included — viz., the axletrees, the beams, the connecting rods, the guides, the eccentrics, &c., and formed of smaller proportions. Now, there is a very important fact connected with engines — viz., the circumstance that the friction does not depend solely on the pressure, but on the degree of fitness of the metal to support the pressure without alteration. Thus, when the state of the carriages becomes altered, the friction acquires immense influence; the bodies become heated and reduced from the filing, arising from the grip they have of each other; they also sometimes become melted. The rubbing surfaces are therefore kept constantly oiled, to prevent any alteration taking place; and this is more especially necessary with locomotive engines, as these surfaces are generally reduced almost to the minimum limits commensurate with the amount of pressure which they have to support. The least negligence on this point is consequently attended with serious consequences—the first, from its increasing the resistance of the engine considerably, and often stopping its progress; secondly, from its increasing the wear of the carriages; and, thirdly, from its causing the rupture of the pieces, in consequence of their becoming heated, and the strains to which they are subjected.* If the carriages become

* We can readily understand the importance of greasing, since the coefficient of iron rubbing on brass, when the surfaces are well greased, is from 0·07 to 0·08 of the pressure; when the surfaces are only oily and damp with water, it is equal to 0·19; and it amounts at length to 0·25 when the surfaces are but slightly oiled.

heated in the smallest degree, they are subjected to great pressure, and the relative hardness of the metals in contact is instantly changed, and the adherence between their surfaces increased, so that they become full of holes and impaired, and oil will never restore the delicate finish which is thus destroyed.

A constant attention to the greasing, therefore, constitutes one of the surest means of preservation, and of ensuring good work in the locomotive. Another circumstance, no less necessary, is the maintenance of the whole of the several pieces in a condition as near their original form and mounting as possible. An engine is composed of so many pieces, and is subjected to such strong vibrations under the influence of shocks, and from the sudden and incessant strains that it is subjected to, that it yields in a certain degree at its joinings. The engine-driver should direct his attention to the prevention of this movement, and he should not allow of any more play in the carriages than is necessary; he should replace those pieces which become worn, and tighten those mountings as they become loosened. The several joinings are, moreover, disposed in such a manner as to counteract the difficulties connected with them, and exhibited with all the pieces thrown in friction with each other.

13. *On the Adhesion.*—It was once supposed that the adhesion existing between the wheels of the engines and the rails was not sufficient to admit of their conveying great weights, which led to their making the engines move on propellers or levers. But it was soon found, however rough the surfaces in contact, that the adhesion of the wheels to the rails was quite sufficient; and, moreover, that the propellers or levers could only be employed for a very slow rate of propulsion.

This adhesion varies in practice, according to the state of cleanness of the rails, from a fifth to a fifteenth of the weight bearing upon the driving wheels of the engine; and as this weight is generally about five tons, the wheels are not able, consequently, to exert an effort exceeding 2205 lbs., or 706 lbs. at the least, without stopping, which much exceeds what is

required for ordinary work; the weight of the train is in fact divided into two parts—viz., the engine and the carriages. The friction of the engine is equivalent to 18 lbs. per ton, and that of the carriages to about 9 lbs.—and supposing the engine to weigh 10 tons, would give 176 lbs. as the friction of it. We have, therefore, 2028 lbs. and 550lbs. respectively left for the friction of the load, which the adhesion is equal to, and which afford a traction sufficient to propel 230 tons as a maximum, and 62 tons as a minimum.

The ordinary passenger trains, consisting of six carriages, make a weight of 30 tons when filled with passengers; and the amount of adhesion requisite to overcome this load would, therefore, be represented by a weight of 265 lbs.—and, together with the engine and tender, of 485 lbs. at the utmost. The limits of the adhesion being generally from 1-6th to 1-10th, it is, therefore, sufficient, if the driving-wheels of the engine support a pressure or load of $2\frac{1}{2}$ tons in ordinary work, being limited to trains such as we have before stated.

But this is far from being the case; the weight of a locomotive of 12 tons being distributed as follows:—

Weight on the driving-wheels . .	$5\frac{1}{2}$	tons.
„ „ fore-wheels . . .	$4\frac{1}{2}$	„
„ „ hind-wheels . . .	2	„
Total . . .	12	tons.

This division possesses the advantage of allowing an engine to draw both light and heavy trains; but, on the other hand, it likewise has a serious effect upon the railway, being the cause of great wear, and of altering the position of the rails, whereby they frequently require repairing.

The injurious effects of heavy engines have been incontestably proved from the results of experience.

The Liverpool and Manchester Railway was laid with rails of 44 lbs. at the period of its opening; the weight of the loco-

motives being five tons. The insufficiency of the latter became apparent in the course of a few months, from the lightness of the several parts and the motion which they partook of at their joints, also the weakness of the surface of the furnace of the boiler; the weight was therefore increased to seven or eight tons; but upon the rails being subjected to these weights, together with the great velocity of the engines, the rails were soon reduced to a very bad condition, the greater part of them becoming broken or bent.

14. *Of the Effects of Locomotive Engines on the Rails.*—It is easy to account for the effects of locomotives on the rails, since they are wholly attributable to radical defects in the mode of laying—even with that followed at the present time —defects, moreover, well known to engineers, and which they endeavour to remedy.

A railway is simply laid on the ground; it is not attached by any more than its own weight and that of the slight beds of earth or sand inclosing the sleepers. The earth on the outside of the line of rails becomes flattened by the weight of the locomotive engine, and sinks according to the elasticity of the soil, and in proportion as the rails press upon a large or small portion of its surface; and as the rails follow this inflexion when they are pressed down by the engine, they consequently rise at each end, and produce an undulating motion every time a train passes over it. The effect of this is so powerful, that on slopes of 1 in 70 to 1 in 90, the rails imperceptibly descend, from the mere influence of the work.

The consequences of this general undulation of the rails would not be of much importance if the inflexion was limited to the elasticity of the earth, but this is far from being the case. The vibrations have also another effect, unconnected with that inherent in the earth, which consists of the unequal resistance of the rails; the right side of the joint of a rail does not, in point of fact, offer an equal resistance with the

other parts; the weight, therefore, in passing over this part, is carried upon a weaker surface of earth, and the bending of the rails at this part is considerable, and it is followed by their rising up immediately after the passage of the weight. The sleepers at these parts become detached from the soil, and are forced down upon it with a violent shock every time they have to support the weight of the wheels of the carriages; the soil thus becomes more and more depressed. The amount of these vibrations, which are due to bad laying, does not probably exceed one-twelfth of an inch, or a quarter of an inch at the most; but this is sufficient to occasion shocks at each length of rail, which is announced by a sort of beat from the different levels which the joinings of the rails take. Those which are subjected to the action of the load become sunk, while the others remain elevated, and the wheels receive a shock in passing over these obstacles, which causes a noise proportionate to the same.

One can readily conceive, after this, that a railway formed with the 44 lb. rails, must be soon destroyed when subjected to such heavy engines and carriages, and moving at such great velocity. The engineers were, therefore, under the necessity of taking up these description of rails immediately, for the evil increased with a rapidity truly alarming.

There were two remedies proposed; the first was to replace the 44 lb. rails with rails of 66 lbs. per yard. But as this operation could only be effected progressively, it was inapplicable; they therefore determined upon adding two more wheels to the engines, thereby making a total of six wheels. It had in fact been remarked, that the injurious action of the engines on the rails proceeded from the manner in which the wheels passed over the joints of the rails, from the action of the vibrations before described. They contented themselves with carrying a portion of the weight of the engine on the hind wheels at the time of pitching. The wheels are placed in such a manner as to carry but a very small portion of the

weight when the engine is empty, in order to prevent the jerking of the springs; since, when the engine is filled with water, the springs are loaded with about 1100 lbs. This remedy, however trifling it may appear, was found to answer beyond all expectations, as it soon became evident that the hind wheels bore a considerable portion of the weight of the engine at the period of jolting, by which the derangement of the railway was arrested. They also attended diligently to replacing the light rails; but even this would have been unnecessary, had not the engines moved with such great velocity.

It is unnecessary to explain the reason of the cranked axle of the four-wheeled locomotives being forcibly loaded with more than half the weight. When the cylinders are placed between the wheels, it follows that the cranks of the axle are placed in front of the fire-box, and that a considerable portion of the engine is situated behind the cranked axle. The fire-box, the square part of the boiler, the platform for the engine-driver, have a false bearing, as we may say, beyond the cranked axle, and therefore load it immoderately.

We may also remark, that six-wheeled locomotives were not introduced to distribute the weight equally, but as a means of economizing the road, by momentarily sustaining, during the running; the force bearing upon the driving wheels upon their becoming checked. There are gradients on the Liverpool and Manchester railway of 1 in 100, which render it necessary to secure the greatest amount of adhesion; wherefore the weight carried by the driving wheels has not been diminished. The frames of locomotives with six wheels differ from those with four, merely by their having two additional wheels at the back, which are serviceable at the time of jolting. This modification, although suitable for railways, such as the Liverpool and Manchester Railway, upon which the gradients are very changeable and

steep, is unfit for others. The locomotives, in fact, ought to be constructed expressly for the railways on which they are intended to be employed: if a line is short, the departures are frequent, and the trains generally light; if the gradients are slight, the force exerted by the engines will be nearly equal throughout the whole line; and as this class of work does not require a considerable effort, the power of adhesion need not be so great. The weight borne by the driving wheels may, therefore, be considerably reduced; but as this weight cannot be decreased without loading the fore wheels much more than the hind ones, the small diameter of the fore wheels consequently causes a great increase of the friction; as the friction increases in inverse proportion to the diameter of the wheels. It is therefore impolitic to take the weight from off the large wheels and place it on the smaller ones. It is much to be regretted, that the diameter of the front wheels have not been uniformly increased, as it is very probable that the advantages connected with it would soon be manifest, and that it would effect a great saving in the expenses of repairing the way.

The following further advantages have resulted from the addition of two extra wheels to four-wheeled locomotives—viz., it has prevented their rebounding laterally, from one side to the other, with such force. The machinery is also better preserved, the joints are better maintained, the escape of steam at the tubes is rendered less frequent, and, to conclude, in the event of the cranked axle becoming broken, they would protect the train from all damage.

Respecting the frames of locomotive engines, we may remark, that the plan of arrangement has been a subject of much controversy, whether they should be placed on the outside or on the inside of the wheels. Experience has decided in favour of the former, and they are accordingly constructed on that principle. If a perfectly rigid shaft were urged in a rotative direction by a rectilinear force, it would revolve with

a degree of firmness proportionate to the distance its carriages were placed apart. If a cranked axle be supported by carriages situated near its centre, and impelled by forces acting in contrary directions, as those transmitted to it from the cylinders, it would cease to be perpendicular to the movement of the pistons, upon the carriages becoming the least worn, and would form an angle proportionably large, accordingly as the carriages were placed near the centre. The flanges surrounding the wheels would therefore knock against the rails, and the engine undergo violent lateral movements from its direct course, which would be dangerous, on account of the great velocity. A like effect occurs when the cranks are placed at the extremities of the axle, instead of near the middle of it, as in the case of engines having the cylinders placed on the outside. The wear of the carriages, also, has the effect of increasing the force of the lateral movements considerably.

15. *Of Locomotives employed in conveying Goods.*—It is customary, in the conveyance of goods, to employ engines with their driving-wheels coupled to the fore ones, which is effected by connecting rods; in which case the fore-wheels are of equal diameter with the driving-wheels. This coupling possesses no other advantage than that of increasing the power of adhesion, by allowing the fore-wheels to partake of the weight carried by the others. The weight supported by the wheels of the engines employed on the Liverpool and Manchester Railway is generally about five tons; and taking one-fifth of this weight as the maximum amount of adhesion, would be sufficient to propel 250 tons on a level; but the minimum amount of adhesion being no more than one-fifteenth, the engines would not be able to advance with a load a little more than one-third the weight of the above, without slipping.

The ordinary passenger-trains on this railway are from about one-third to one-fourth the weight that the engines are able to propel at a slow rate of speed throughout the whole

line, the inclined plane of 1 in 100 alone excepted. The power of the engines, calculated exclusively from the dimensions of the cylinders, also the cranks and wheels, is therefore three or four times more powerful than the resistance which they have to overcome. There is, consequently, always sufficient adhesion for these trains, and stoppages through slipping are imperceptible, and very rare.

This is not the case with the trains employed in conveying goods, as they are considerable. The adhesion is required to form an equilibrium with the power of the engine when the plan of coupling is adopted. Notwithstanding this coupling of the wheels is attended with great inconvenience; it causes considerable friction, on account of the want of uniformity in the diameters of the wheels, in consequence of the wear of the tires and felloes, and of the carriages, for adjusting the connecting rods.

It also renders it very difficult for the engine to work curves of small radii.

The coupling rods are also liable to be broken, and to derange the engine, by catching against the ground.

The couplings are subject to derangement from high velocities.

In the event of the wheels of a coupled engine slipping, for instance, in time of snow, the greater number of pieces in motion sustain a considerable degree of torsion.

The coupling rods afford more adhesion than is necessary, under favourable circumstances, and therefore become an embarrassment.

These inconveniences induced Mr. Melling to employ another method of transmitting the stability of the driving-wheels to the front ones, on the Liverpool and Manchester Railway. This consists in placing a band, bearing upon the periphery of the tires of each, which is pressed freely and with considerable force, by means of small pistons and cylinders, in which steam is introduced when the adhesion of the wheels requires to be increased.

The details of the success of this application is given in a very interesting article written by Mr. Edward Woods, and printed in the second volume of the "Transactions of the Institution of Civil Engineers."

16. *Of the Tender.*—A sort of wagon is attached at the extremity of a locomotive engine when in motion, which is called a tender, and which is generally mounted on four wheels, and sometimes on six. It contains water and fuel sufficient to feed the boiler and grate during a run of about twenty-five miles as a maximum, and about fifteen miles as a minimum. In order to supply trips exceeding these limits, reservoirs of water and depôts of coke are arranged at convenient distances on the line, which enables them to extend their run to distances which are only limited by the strength of the engines.

The tender is joined to the engine which it accompanies by a bolt, which is adjusted to fit into a staple. This bolt should be capable of resisting the entire power of the engine. The reservoir of water communicates with the engine by the two pipes of the feed-pumps; the connexion of the barrels of the pumps is made by means of a flexible pipe, denominated hosing, whose nature is such that it can readily yield to all lateral and vertical movements of both engine and tender; the movements are inevitable, for reasons before stated, from the little stability of the railway, the great velocity of the engines, &c. The bolt admits of every movement, except that of lengthening.

Tenders of good construction should present an appearance of lightness combined with solidity; the joints of the iron plates composing the reservoir of water should be well stopped, the cocks of the supply pipes to the pumps also require to be made perfectly water-tight, which is a condition they do not always fulfil. The fuel in the tender is placed upon a level with that in the fire-grate. The wheels are wedged on the axletrees similar to those attached to the engine, and the weight of the tender is suspended on springs, to remedy the

abrupt motion of the water. There is a hook at the back of the tender, which is attached to a powerful spring, to neutralize the effects of concussion, and for the purposes of traction, and it converts all shocks occasioned by the jerking of the engines, which are sometimes very abrupt, into pressures more or less strong accordingly.

CHAPTER II.

DETAILED DESCRIPTION OF THE COMPONENT PARTS OF A LOCOMOTIVE ENGINE, AND THE NATURE OF THEIR EMPLOYMENT.

THE preliminary observations upon locomotive engines in the preceding chapter, describe the nature of the functions of the several parts when connected together sufficiently, to enable us to revert to each separately, and examine them in detail; we shall therefore proceed in the same order as before, and examine each feature successively, viz.—

1st. The fire-box, the pipes for conducting the flame and smoke, and the chimney.

2nd. The boiler and its accessary parts.

3rd. The pumps.

4th. The steam entrance pipes; and those for the distribution and escapement of the steam.

5th. The slides and the slide-boxes, the cylinders, the motion of the eccentrics for the distribution, and the apparatus for conducting and directing the steam at the command of the engine-man.

6th. The pistons, piston rods and guides, and the conveyance of their motion to the cranked axles.

7th. The weigh-bars, or cross-beams, and outside frames.

8th. The springs.

9th. The wheels.

10th. The connexion of the locomotive with the tender.

11th. The tender.

12th. The expansion stop.

We will take, for our first examples of engines, Jackson's locomotive with four wheels, and the six-wheeled engine upon the Paris and Versailles railway.

17. *Of the Fire.*—The apparatus for generating steam in a locomotive engine may be divided into three distinct parts:—the first is called the *fire-box*, and is appropriated to the fuel; the second is for the reception of the water and the steam generated from it, which is called the *boiler:* the third is intended as a receptacle for the effluvia from the flame, smoke, and the produce generally from the fuel; it is called the *smoke* or *cylinder-box*, from the lower part usually containing the cylinders.—See Plates 7, 8, 9, 10, 11, and 12.

It will be perceived, that the fire-box is inclosed at every part except the bottom, which is occupied by the grate, and the side next the boiler, which is pierced with a certain number of circular holes, for the purpose of receiving the smoke-tubes.

There is a space from about 2⅓rd inches to 4 inches between the two casings, which is appropriated to receive the water, which is heated by the action of the fuel.

The external casing is formed of sheet iron about a quarter of an inch in thickness; the internal casing is formed with copper sheeting, of a greater thickness than the former, on account of the high temperature which it is required to support—it may be increased to upwards of half an inch in thickness. The side which receives the tubes is formed double, or in two thicknesses, but this plan is not adopted in any other part of the boiler; the lower part of the side next the boiler is not increased in thickness, the upper part being increased in order to compensate for its being weakened by the holes formed in it, and on account of its receiving the direct heat of the flames, which are drawn towards it by the draught.

We have explained, in the last chapter, that the motion of the engine is effected by means of the pressure of steam upon the pistons; this pressure, which is first called into action in the boiler, naturally acts upon all the sides. And as loco-

motive engines are formed on the high-pressure principle, on account of the great power which is required, and the simplicity of this method of construction, each casing is consequently submitted to a considerable pressure, as will be shown by the following calculation.

The effective pressure ordinarily occurring in locomotive engines* is about 60lbs. per square inch, which is equivalent to four atmospheres and a quarter. From which data we find, generally, that when the interior surface of the fire-box equals about 37 square feet, it supports a pressure of 318,630lbs. The pressure of the steam is also exerted on the external casing of the fire-box, the surface of which is from 145 to 175 square feet, which is subjected to a pressure of 320,225lbs.; the pressure on the cylindric part of the boiler is 507,150lbs. for about 152 square feet, and the tubes sustain a pressure of 3,858,750 lbs. upon 1160 square feet.

Thus we see what an enormous pressure the casings of the boilers are subjected to, when the steam is generated under high-pressure. It is on this account that the boilers of stationary engines are formed cylindrical, as it affords the greatest resistance, but the necessity of obtaining an extensive surface in locomotive engines for the furnace, in a small space, *of reducing* the quantity of the water, and the space appropriated as a reservoir for the steam, has obliged the manufacturers to abandon the cylindric shape at certain parts of the boilers. They have even been under the necessity of employing plane surfaces, although so much more readily put out of shape by the force of the pressure.

It is, therefore, necessary to fix the last description in such a manner that they may be enabled to resist these high pressures. The interior and exterior side casings of the fire-box are, therefore, tied together by tie-bolts, which effectually prevent any disarrangement or rupture. They are seldom formed of iron, but generally of copper, which, although it

* That is to say, exclusive of the atmospheric pressure.

offers less tenacity, resists oxidation better, and is therefore more likely to last longer. They are made to screw throughout their entire length, and are riveted or otherwise fastened at each end; the heads prevent the framing from breaking asunder, and the thread of the screw opposes their drawing towards each other. Bolts, made either of cast iron, brass or copper, answer the purpose equally well, (See fig. 5, Plate 8.) The external casing of the front is joined by iron rods to the opposite casing of the smoke-box at the upper part. These rods require to be tolerably numerous, to give effect throughout the entire length of the boiler; they may, however, be safely reduced to three in number, by riveting a strong bar of iron with a projecting angle on the inside face of the casing of the boiler, and placed in a horizontal position at the level of the rods; this piece has the effect of increasing the effect of the sheet iron considerably, so that it only requires to be held at a few places.

The covering of the fire-box is plane, like the side casing, but does not possess the advantage of being able to be joined to the opposite casings. It is rendered inflexible by the help of brass bars, or by strong bridging irons, G, (See 1, 2, and 5, Plates 7 and 8): six or eight in number, and which are fastened by iron bolts, *b*, *b*. We see, then, that all the flat parts are secured by bolts, which enables them to resist the force of traction and pressure, with the same efficacy as cylindric figures. The casings of that part of the boiler in which the tubes are situated are sometimes held in their proper position by a number of bolts placed parallel with the tubes, but which are not employed with any locomotives upon the St. Germains railway. There are one or two iron pins at the lower parts of some of them, but the fastenings of the tubes are considered sufficient to resist the traction.

That portion of the boiler situated above the fire-box, is circular, constituting in fact a semicircle, and it is enabled, by reason of its form, to resist the pressure of the steam in the interior. The fire-box is sometimes made of a single

piece of copper, and in other cases of a single piece of sheet iron; although this is very seldom adopted, being a very bad method; but the most general plan consists of forming it of five sheets of copper fastened together by rivets. Respecting the external part, the sheet iron plates composing it are joined, lapping over each other, (See fig. 5, Plate 7.) and they are fastened in the angles by means of flat angle irons. (See fig. 3.)

The right angle turnings are frequently formed by forging and raising one of the iron plates with the hammer; this method, however, is very liable to weaken the plates, although they seldom yield much to the action of heat, as long as they remain in their natural state. It therefore becomes necessary to employ angle irons whenever the sheet iron is not of first-rate quality, or the work is not executed with skilful workmen, although their employment appears the least satisfactory. The door of the grate, intended to hold the fuel, and which is situated upon the front, is formed of two plates of sheet iron, (E, fig 5, Plate 8,) a space of from 2 to 2½ inches being left between them, which contains air, and is intended to prevent the loss of heat, and to preserve the door from damage.

It has been attempted to form the interior of the fire-box of iron plates, as before stated, but its rapid wear and the workmanship requisite in replacing it, obliged the manufacturers to abandon it, and to adopt copper, which is found to be the most economical, notwithstanding its great price, on account of its lasting qualities.

18. *On Fire Grates*.—The grate of the fire-box is composed of 12 to 15 iron bars, standing about 2¼ to 2¾ inches high; they are formed larger at their extremities than at the middle parts, in order to afford sufficient opening for the passage of the air, which feeds the fire. This is also necessary to enable the ashes and cinders to fall between them and pass away. They ought to be regulated according to the quality of the coke employed. It is known that good coke liquefies its slag, and causes it to flow, whereby the bars are

enabled to be brought nearer together, which prevents the loss of fuel on the road, and there is scarce any occasion for poking the fire at the stations.

The surfaces of the grates of locomotives with four wheels are equal to about 20 square feet, and with those of six wheels 28 square feet.

The distance from the grate to the first tier of tubes is 1 foot 4 inches with the four-wheeled engines, and 1 foot 8 inches with the six-wheeled.

The four-wheeled engines can, therefore, contain a mass of fuel equal to 8·83 cubic feet, and the six-wheeled 19 cubic feet.

The amount of fuel is not strictly regulated by the lowest tier of tubes, since it generally rises above them, which consequently makes an addition of a quarter more fuel to the proper quantity which the grate is capable of containing, and gives 10·72 cubic feet for the four-wheeled locomotives, and 22·78 cubic feet for the six-wheeled, which makes a weight of 144 kilog. (317 lbs.) for the four-wheeled locomotives: and 270 kilog. (595 lbs.) for the six-wheeled; supposing the fuel to be coke, and that it weighs about 450 kilog. to the cubic metre, (925 lbs. to the cubic yard.)

Now it is known that one kilog. (2·205 lbs.) of coke contains 6500 units of heat,* therefore, the number of units of heat contained by the four-wheeled locomotives, is kilog. $144 \times 6{,}500 = 936{,}000$ units of heat: of those of six wheels, kilog. $270 \times 6{,}500 = 1{,}755{,}000$.

It is necessary for the bars to be moveable, in order that those which become destroyed by fire may be readily replaced, and that the fire may be removed quickly, in case of accident or stoppage.

They have adopted turning grates in several locomotives. Three or four bars are run together in the middle, in such a manner as to allow of a rotative movement by means of a

* A unit of heat is the amount of heat required to raise one kilog. of water to one degree, whence 100 units would raise one kilog. of water to 100 degrees, or 100 kilog. to one degree of heat.

hook, *x*, (fig. 5 and 6, Plate 8); they rest on a lever, *a*, *c*, *d*, which is turned when the fire is required to be removed, by means of a handle, *b*.

These grates possess the great advantage of being able to throw off the fire instantly, without casting off the iron grate bars with the live coke, which is an inconvenience, first from the bars becoming burnt, and thereby sooner deteriorated, and also the time lost in looking after them when they are displaced from the engine, after the throw of the fire. This plan, however, has not been generally adopted.

The voids, or spaces, between the grate bars in Jackson's first engines was 2 inches, and the width of the bars about 1 inch. The voids have been considerably diminished in the new engines, being made $1\frac{1}{8}$ inches, and the bars 1 inch.

The level of the water in the boiler is sometimes very low, from the negligence of the engine-man, when the rapidity of the motion of the engine agitates the water in such a manner that the metallic parts are left uncovered, and, becoming exposed to the action of the fire, are soon burnt. The following plan has been adopted to prevent this accident, and to warn the engine man; a small fusible plug, *a*, fig. 7, Plate 9, is placed on the higher part of the interior of the fire-box, of such a description that when the depth of water is not sufficient, the boiler becomes over-heated, and the plug melts, when the water and a considerable portion of the steam is thrown on to the fire, which has the effect of extinguishing it.

The ash-pan, which is placed under the grate, is formed of sheet iron; it is open in front and inclosed beneath; the door, which is placed on the front, serves to clean the grate and to take off the fuel when they stop. If the ash-pan is set too low, it is apt to gather up the sand thrown up by the road layers at those parts of the railway undergoing repair. The sand thrown up by the ash-pans when the engine is going at great speed, is discharged on to those parts of the machinery in contact with each other, and consequently fills them with dirt.

The ash-pan is open on the side in the direction of the

motion of the engine, in order that it may the more readily catch the air, and favour the draught, by causing the air to flow in under the grate, with a velocity equal to that of the engine. The velocity of the air at the time of its passage through the grate can be calculated by the quantity of fuel consumed.

19. *On the Tubes for Conducting the Smoke.*—There are upon that side of the fire-box next the cylindrical portion of the boiler, from 75 to 150 holes, which are intended to receive as many tubes. The tubes are generally made of copper, although Mr. Stephenson has substituted brass with advantage.* They serve the purpose of a communication between the fire and the chimney, and afford an escape to the hot air and the gases arising from the combustion. These tubes are forced gently into the holes prepared to receive them, the latter being made exactly cylindric (See fig. 8, Plate 8). They are chamfered at the end next the fire, and in order to render the joints perfectly tight, a steel ferrule is driven on with a hammer. Some manufacturers do not chamfer the ferrules, but the edges of the holes, as shown by the figure, (fig. 9, Plate 8). Each tube should be reduced to the chamfer by an accurate iron mould, previous to fixing the ferrule, and not by the action of a hammer, since this has the effect of causing a protuberance at the mouth of the tube. The purpose of this combination is not merely to tighten the joints by the lateral pressure of the ferrules, but also to prevent the extreme ends of the boiler yielding from the interior pressure of the steam, so that each tube acts as a tie, like those which connect the other fronts of the fire-box. It is to be regretted that the tubes cannot resist the collapsing of the surfaces, as well as its escaping outwards, like the longitudinal ties: nothing is more desirable, as it is this yielding of the ends in the interior which is so often the cause of the steam escaping at this part of the boiler. The iron ferrules are soon worn out, and are, therefore, frequently replaced. The most injurious effects

* Iron, however, is now employed for these tubes.

arise from the unequal action of expansion, which soon shows itself when the fire is suddenly put out: the tubes thrust out at the time that the plates in connexion are collapsing —this is a constant occurrence: in which case the ferrules become displaced and get off the tubes. When the former are made of soft iron, and are driven into the tubes with a hammer, they elongate a little, by reason of the diminution of the diameter, and cease to tighten the tube effectually in the casing; when, on the contrary, these ferrules are made of hard iron or steel, they resist better and preserve their diameter, exert a great lateral pressure, and therefore maintain the joint longer. The diameter of the tubes varies from $1\frac{1}{2}$ to nearly $2\frac{1}{2}$ inches. The thickness of the brass of which they are formed is from $\frac{1}{10}$ to $\frac{1}{15}$ of an inch. When a ferrule or a tube is required to be replaced, a straight cut is made through the entire thickness of the ferrule with a chisel, and the edges of this cavity are raised in the interior, which enables the workman to detach the tubes.

The surface of the furnace may be increased, in stationary engines, according to the quantity of steam required; but in locomotive engines it is necessary to combine the greatest amount of surface in the furnace with lightness and slight substance of metal, on account of the great velocity of the engine, and the circumstance of the apparatus for the generation of steam, the water, and the fuel, being carried along with it, also the boiler and tubes to convey the flame and smoke to the chimney, which system is adopted to the exclusion of all others.

The flame-tubes were first introduced by Mr. Marc Séguin, on the railroad from St. Etienne to Lyons, and it is to this celebrated engineer alone that the discovery is due, by which the engines acquire such great velocity, by generating steam suitable to their wants. The diameter of the tubes can only be determined by experience: there is an advantage in making them small, since the surface of the boiler becomes increased, in a given space, by the number of the tubes; but on the other hand, if they are too small in diameter, it has the

effect of increasing the friction of the air through them, which diminishes the draught; the force of the draught, moreover, draws the small particles of coke and cinders into the tubes, where they soon form an obstruction, and affect the activity of the fire.

But of whatever diameter the tubes may be, they are soon liable to be filled up, unless frequently cleaned, which is performed by means of an iron ramrod furnished with a boss of tow or cloth at the end.

The want of durability of iron tubes, and the workmanship required in replacing them, led originally to their being abandoned, and the high price of brass induced the manufacturers to adopt copper tubes, which also last the longest.

The wear of the tubes depends on the friction of the cinders, on the oxidation, arising probably from electro-chemical causes. The parts connected with the casing next the fire are very soon destroyed.

When a tube becomes perforated from the effects of friction, use, or the pressure of the steam, it is instantly known, as the water escapes through it, and extinguishes the fire. It is not necessary to remove the defective tube immediately: a wooden plug is generally driven into the end next the fire-box, which is preserved from its effects by the water contained within it. Now, when any large number of these tubes become pierced with holes and plugged in this manner, the section of the passage for the smoke is rendered too small, and the engine has not sufficient draught; the tubes must, therefore, be replaced by others. The replacement of the tubes soon becomes necessary with an engine that is in constant work, although it depends much on the care bestowed by the fireman. Their reduction in substance, and consequently of weight, is remarkable: when new, they weigh about 16 lbs. and they become reduced by wear to less than 7 lbs.; they are therefore considerably reduced in thickness, and a greater degree of heat necessarily passes through this diminished substance than usual; it consequently arises, that engines which

have been some time at work obtain more steam from the same quantity of fuel than others. This effect is changed, and even lost, by the least inclination of the tubes to become charged with incrustation. These incrustations proceed from the matter contained in the water, which is generally calcareous, and it at length adheres closely to the several surfaces, thereby causing the heat to be very badly conducted, in spite of the care bestowed in cleaning the boiler. We have before described the remedies employed at the present time, and we may add, that it is a good plan to remove one of the lower tubes, and close the opening by a screw-plug, whereby this part of the boiler may, from time to time, be cleansed of the accumulated incrustations disengaged from the tubes. If this precaution be neglected, an earthy layer will frequently be formed at this part, which destroys the lower pipes by preventing the water from entirely covering them.

20. *On the Smoke Box.*—The front part of the engine on which the chimney is fixed is formed of plates of sheet-iron, of the same shape externally as the fire-box; the casing next the boiler *k* (figs. 10 and 13, plates 10 and 11) is pierced with a number of holes, corresponding to those next the fire-box, and they receive the ends of the tubes which conduct the flame. Referring to other parts, the box is completely closed on every side; the casing which receives the tubes is also subjected to the pressure of the steam. The steam cylinders are also situated in the lower part of this box, and are thus protected from any loss of heat and the condensation of steam, which would otherwise be very considerable: there would be a great loss of power if the cylinders were subjected to the action of the cold air of the exterior. These cylinders are sometimes inclined (fig. 11, plate 10), which arrangement is indispensable when the four wheels are of the same diameter, which is the case when they are coupled, to increase the adhesion.

The diameter of the chimney (fig. 12, plate 10) in the four-wheeled engines is about 12½ inches, and the height from the

rails 12 feet 6 inches. It is fixed on the smoke-box by stay-irons, riveted on, or by cast-iron brackets. The top is enlarged in a funnel shape for the purpose of diminishing the noise of the steam escaping, and it is enclosed with a metal cover, either of iron or brass, particularly in the harvest-season, to prevent the escape of small particles of burning coke. This cover is of a convex shape, and enlarged, so as not to obstruct the passage of the air and the produce from the fuel. The diameter of the chimneys of six-wheeled locomotives is about 14 inches, with a height of 6 feet 6 inches above the boiler.

The chimney cannot be made of greater height on account of the works which they are required to pass under. The chimney would not of itself produce sufficient draught for the necessary production of steam, but it is assisted by artificial means: ventilating and blowing have been tried and found insufficient, and expensive: these have been disused, and the waste steam employed instead. It is discharged into the chimney, where it gives a velocity to the air, which has the effect of drawing off the hot air and flame from the tubes, and producing a supply of fresh air in the fire-box through the grate.

The blast-pipe is formed of a conical shape (figs. 10, 11, and 13, plates 10 and 11). The compression which the steam undergoes in escaping has the effect of prolonging the time of its emission, and thus creates a powerful draught. The production of steam is consequently increased, but the pressure of that arrested for the purpose of creating the draught, acts as it were contrary to the movement of the piston, and tends to diminish the motive power. This loss of power becomes very considerable at high velocities, although it is necessary to employ a portion of the motive force to produce the draught, and the blast-pipe evidently presents the most simple, easy, and powerful means. It remains to be seen whether the mouth of escapement could not be increased during high velocities, without reducing the strength of the draught, which would diminish the duration of the force

acting against the piston. A course of experiments might be advantageously made to determine this important question.

The large door placed behind the smoke-box affords access to the cylinders and tubes, for the purpose of inspecting and cleansing them. There is a smaller door below, to take out the cinders and ashes which may collect in the lower parts.

21. *On the Damper.*—The driver of a locomotive engine should always be master of the fire. This is accomplished by a plate of sheet iron, nearly circular, being placed in the interior of the chimney, which is called the damper, figs. 10 and 14 (plates 10 and 12.) It is formed with a circular opening in the middle of it, and is moveable on an axis, the position of which allows the end of the blast-pipe to enter the hole. The axle is formed of plate-iron, bolted upon each side and finished in a cylindric shape, being connected to the casing of the chimney upon which it turns, and it carries a small crank, which is put in motion by means of a rod, supported on a rest by the engine-driver. The connecting-rod is terminated by three notches, which indicate the three different positions of the damper. This mode of regulating the draught, independently of its efficacy and simplicity, is also useful when the fire is required to be removed, as the latter has the effect of introducing a current of cold air from the exterior, which, together with the rarefaction of that in contact with the heated parts of the boiler, causes a change in the metallic parts, that, although slight, contracts and injures them considerably.

It is necessary to remember that, when the damper is raised, the steam is not visible, on account of the great quantity of hot air which it absorbs; but when it is lowered, the steam escapes in thick dense blasts.

It has been attempted to regulate the draught by several other modes: at first, by merely reducing the strength of the fire, by the introduction of cold air into the chimney through an opening, which the driver effected by means of a handle, and the smoke-doors were employed as a means of clearance.

This method was very objectionable, since it diminished the draught to such an extent as almost to extinguish the fire, the quantity of cold air introduced having been very considerable. It was also injurious, from its affecting the temperature of the iron plates situated at this part of the boiler, which became twisted and deteriorated by it.

Advantage was also taken of the small door situated at the lower part of the smoke-box: although intended specially to remove the cinders, yet it may be used as a damper, by being opened more or less according to the draught required. If this opening is placed too low it is inconvenient, as the ascending motion of the air attracts the cinders and refuse of the fire which pass along the tubes, and which are thrown out of the chimney with violence, and have the effect of befouling the engine and inconveniencing the passengers.

The last inconvenience was remedied by placing a cockade, with moving wings, above the smoke-box, similar to those employed generally for ventilation. The cockade furnished a communication between the external air and the smoke-box, by which the section of the current of air could be diminished at pleasure. This method was superior to that of opening the door of the fire-box, since the latter plan introduced a quantity of cold air above the fuel, the whole of which operated by diminishing the draught. It did not, however, proportionately diminish the quantity of fuel consumed: it was also accompanied by a chill, which had the effect of producing sudden contractions, and was highly injurious.

Stephenson's damper, which we described first, is much to be preferred; there is also an excellent contrivance connected with it—viz., another exit for the steam, which is situated at the lower part of the blast-pipe. This extra pipe opens externally under the cylinder-box, and is furnished with a cock, to regulate the size of the orifice of escape. When it is desirable to diminish the draught, a portion of the steam is let out through this pipe. Now as the power of the draught is produced by the volume of steam passing from the blast-pipe

into the chimney, when a portion of the waste steam escapes into the air by another channel, although the quantity of steam remains the same, it is divided, and that portion which passes up the chimney is reduced; also the time it occupies in escaping, and the draught. This contrivance also has the good effect of diminishing the pressure of the steam at the back of the piston, which pressure always exists in a tolerably high degree, on account of the diminution of the upper end of the blast-pipe. This lower cock is within reach of the engine-man, who is thus enabled, by its agency alone, to regulate the draught.

22. *On the Boiler and its Appurtenances.*—The general plates of locomotive engines and details sufficiently exhibit the construction of the boiler. It is formed of strong sheet-iron, like the covering of the fire-box, and secured in a similar manner, the smoke-tubes extending throughout its entire length. The boilers of the old engines contain water to a height of 11¾ inches, and the new ones to 13 inches. The volume of water contained by the former was about 35·99 cubic feet, the new locomotives, with six wheels, hold 58·41 cubic feet. The size of the steam-chamber of the first was 18·59 cubic feet, and of the second, 23·01 cubic feet. The entire area of the old boilers was, therefore, about 54·58 cubic feet, and of the new ones, 81·42 cubic feet. It will be perceived that the steam-space is about one-half the size of that appropriated for water. The water situated next the upright casing and top horizontal casing is subjected to the direct influence of the fire; that surrounding the tubes only receives the caloric, which is carried along with the flame and hot gases drawn towards the chimney by the draught. This water is thus rapidly heated, as before described, whereby currents are formed throughout its entire body, in such a manner, that the water in contact with the casing is replaced by fresh as it becomes heated, until the temperature is established equally throughout; yet it is not perfectly uniform, but that portion in immediate contact with the fire is of a higher temperature

than the remainder. The cylindric portion of the boiler is covered with boarding, which prevents a loss of heat, wood being a good non-conductor of caloric. This covering is secured by iron hooping, fastened at the extremities. The surface of that portion of the furnace which communicates the action of the fire direct to the water, is 32·47 superficial feet in small engines, and 52·16 superficial feet in large engines. The amount of tubular surface is 246 superficial feet in the first, and 579·7 superficial feet in the other. If we suppose, with Stephenson, that the heat passing through the tubes is but one-third of that which passes by the surfaces directly exposed to the fire, and reduce the surfaces after this proportion, there would be 114·17 superficial feet for the first, and 216·53 superficial feet for the last.

There are several appurtenances connected with the boiler; some are for the purpose of ascertaining the level of the water, as the cocks and gauges, and others indicate the pressure of the steam and regulate it, as the safety valves (A and B, plate 13); others afford a means of cleansing and inspecting the inside of the boiler, as the cocks and the man-hole (C, plate 13); others, again, are employed in replacing the water passed in the form of steam, as the pumps, which we shall examine in another part. Fig. 15 (plate 13) shows the several appendages which are placed on the top of the boiler.

23. *Of the Water-Gauge.*—The water-gauge is placed on the front casing *a a*, fig. 16 (plate 13), and consists of a very thick glass tube, fixed in brass sockets at top and bottom. Tow is introduced between the sockets and the glass tube, to render the joint tight, the tow being dipped in mastic of minium, and it is forced between the sides of the glass and the socket by a ring screwed on the brass socket, in the form of a stuffing-box.

Metallic tubes *b b*, fig. 16, are connected with each of these pieces, which are furnished with cocks in the middle, and are tapped at their extremities, and screwed to the side of

the boiler, one of them communicating with the steam, and the other with that portion containing water, in such a manner that the tube is situated under precisely similar circumstances as the boiler. There is a metallic piece screwed to the socket *a*, at the lower part, which is furnished with a cock, whereby the glass tube is emptied; the upper screw *d*, serves to clean the cock when requisite.

The tubes *b b* are in communication with the interior of the boiler. Upon the upper and lower cocks being turned, the water rises in the glass tube to the same level as that in the boiler, and enables the engine-man to judge of the supply. The cocks are also serviceable in cutting off the connexion between the boiler and the gauge, in the event of the latter becoming broken or defective from use. The tube may be cleansed by passing a current down it, through the cock *r*, which also serves to pass off the steam-bubbles arising from the rapidity of the ebullition of the water, which disguise the true level. The channel of communication should be formed with a very small cross section, to lessen the amount of oscillations which the rapid motion of the engine produces on the water. The two small bolts *c c* are tapped, by which the pipes *b b* are opened and cleaned when they are obstructed by deposits, which is effected by means of brass wire.

A knowledge of the precise level of the water in the boiler being so important to the driver, other means are provided to assure him correctly of it. Two or three cocks are placed for this purpose at different heights, and in positions corresponding to the levels which require to be constantly preserved in the boiler.

The driver should know, from experience, the cocks which should give forth steam, and those which should deliver water, and he should frequently try them, to avoid burning the upper part of the furnace, which would be sure to take place if the body of water surrounding it is too small.

The fusible plug would partly remedy any neglect; but if the latter should be called into requisition during the running

of the engine, all further progress would be rendered impossible.

24. *On the Safety-Valves, Man-hole, and Blow-off Cocks.*—The safety-valves are always two in number, and formed with springs and levers. One of them is sometimes loaded to a certain extent, and placed out of the reach of the fireman. These valves are placed at different parts of the boiler, and their position is not of great consequence. The lever-valve rests on a slight footing placed on the top of the boiler A A, fig. 17 (plate 13), and is bolted to the copper lugs *a*; the valve *b* is of brass, and formed with chamfered edges; it is guided by a rod in the centre, which runs through a collar set on the boiler. The valve should not allow the steam to pass, when the pressure that it supports externally is equal to the interior pressure of the steam, the former being regulated beforehand. The socket-piece *d* supports a small turning point *e*, on which the lever *f* is pinned, which directs the pressure of the valve by the help of the connecting-pin *g*. The other end of the lever is terminated by a flat piece, through which a rod passes, and a screw-nut V is placed over it. The rod is connected with a spring below, which is secured in a box; the motion of the lever consequently operates upon the spring, and either compresses or extends it. The box is formed of metal, with a flat face on one side and a circular one on the other, and it is fixed on the boiler by means of a bolt *t*. Plate 14 exhibits sections of this spring. If we ascertain the resistance due to the elasticity of the spring, by experiment, multiply it by the great lever, and divide by the smaller one, (taking account of the weight of the lever B, the valve, and the balance,) it will give the pressure of the steam on the valve.

A moveable weight is adopted in fixed engines, instead of the employment of a spring balance, which, being placed in different positions, increases or diminishes the pressure on the valve. This method is impracticable with locomotives, on account of their velocity and vibration, which would change

the position of the counter-weights. The safety-valves are liable to err—first, from the variation in the elasticity of the spring, which, by degrees, becomes strained; next, from the inequality of the surface on which the valve rests, increasing the resistance at the time the steam is passing out; and, lastly, from the errors of the manufacturers in graduating the balance, through their neglecting to take account of the weight of the lever, &c. It is, therefore, necessary to test their correctness by means of a dynameter, that can be momentarily fixed to the engine. The lock-up valve *f*, (plate 15), fixed with springs, is of different construction to the preceding; it is enclosed in a box, out of the reach of the driver, who cannot, therefore, increase the pressure. Fig. 20 (plate 15) gives sufficient idea of it.

The boiler is cleansed by means of ejecting the water, two cocks being placed at the bottom of the plate forming the covering of the fire-box. There is an aperture on the top of the boiler at C, 1 foot 6 inches by 1 foot 9 inches (fig. 15), by which a man may descend into it, to inspect the tubes or to clean and make any repairs. This opening, which is called a man-hole, is finished with a top of a circular form, to resist the pressure of the steam, and is properly secured with lugs, and bolts. There are two holes in the external covering of the fire-box, which can be opened whenever required; for instance, when it is desirable to clean the boiler, and rid it of any sediment that it may have collected. This operation is performed when the engine is cold. The men introduce a jet of water through these doors, which cleans the casing; they also employ a crooked iron rod, to remove the sediment which does not come off at the first washing. It is important that the apertures should be conveniently situated, so that all the several sides may be operated upon.

25. *On the Steam-Whistle.*—This little apparatus is fixed on the top of the fire-box, and is intended to give notice of the approach of the engine. It is sufficiently represented in Fig. 21, (plate 15). The steam passes out through the open-

ings *a* with a whistling noise, which is produced by the contraction, and the obstacle which the small upper dome presents to the lower one.

26. *On the Feed-Pumps.*—These pumps are fixed to the great cross-frames, or weigh-bars, of the engine, and are employed to replace the water constantly escaping from the boiler in the form of steam. They are constructed of various forms. Fig. 22 gives views of those employed in small four-wheeled locomotives.

The pipe *b* communicates with the tender following the engine, and the pipe *a* conducts the water to the boiler. There is a plunging piston in the body of the pump, of which a representation is given in fig. 22. It consists of a hollow cylinder, formed of copper or of turned iron, in which an iron rod is passed, which is furnished with a screw at the end for the purpose of screwing into the hollow piece *j*, which fastens it to the piston-rod *p*; the piece *j*, however, is not tapped, but has a moveable nut on each side, and it is by the help of these screw-nuts that the piston is adjusted to the exact length, and in such a manner that it is enabled to plunge to the bottom of the body of the pump without touching it, the other unites the piston of the pump with the interior rod. The backward-and-forward action of this piston causes a suction and a forcing-movement alternately; the suction-movement raises the valve *k*, and brings the water into the pipe *c*, and the compressing-movement lifts the valve *k*, and shuts the preceding one, and refills the pipe *a* with water.

The barrel of the pump *c* is formed either of cast iron or of copper; being larger in diameter than the piston, it does not require to be polished. It is rendered water-tight by means of a stuffing-box, as shown in fig. 23, (plate 16,) or a metallic bush, screwed and polished, as in fig. 22. There is a small pipe T, fastened with screws to the extremity of the barrel *c*, and furnished with a trial cock *g*, the key being connected by a lever with a handle within reach of the engine-driver, by which he ascertains whether the pump gives water and works well. A cylinder, *e*, is secured in the barrel by a proper

joint, in which the suction-valve works; and there is another pipe, *f*, in which the compression-valve works. The whole of these barrels are formed of brass. There is a cock situated below the rising pipe, which is employed to shut off the passage of the water in the boiler when the valves require to be inspected; a double valve is, however, preferable to a cock, as the latter might be forgotten to be opened, when the pump would certainly be broken, from its being unprovided with any valve.

The valves consist of turned copper balls, resting on brass spherical seats, and their movements are directed by guides, with four branches, *k k*. The lower suction-valve frame is maintained in its proper position by the pipe itself; the upper frame is pressed and maintained by the ball *b*; the pipe is furnished with a cock before it reaches the tender, in order that the engine-driver may remove the reservoir of water from the action of the piston when he pleases, in which case it runs to waste. These two pumps are fixed to the frame of the engine by means of the lugs *m* and *m'*, and are placed exactly parallel to the motion of the piston-rods. This parallelism, however, is frequently destroyed from the effect of the guides, rods, or pistons. An allowance is made for play at the points of attachment of the pump-rod with that of the piston.

Fig. 23 shows a section of a feed-pump employed by Stephenson. The barrel of the pump C is formed of hollow iron, $1\frac{5}{8}$ inch diameter within, with a thickness of 5-12ths of an inch.

The piston which moves in this cylinder is $1\frac{3}{8}$ inch; it will therefore be perceived that room is left in the barrel of the pump for play.

The joints of the suction and compression-pipes of this pump are different to those before described; the two parts intended to be joined are formed with a chamfer, and enter one in the other, and are further covered by the collar *h*, which forces them close together, and is screwed on from the outside.

The two pumps act precisely alike; one, no doubt, would be sufficient, even without being constantly at work, but the other is necessary in case of accident, or when one is out of order.

The feed-pumps are sometimes contracted with valves of the form shown in plate 17, instead of balls, and which are employed in Bury's locomotives. The entire contrivance is fixed to the large weigh-bars by the lugs *o*. The piston P acts in the same manner as those of other pumps. The valves are held in their places by the stops *p*, which prevent their rising too high, and force them back to their original position: these stops are fixed to the barrel of the pump by bolts. The cock *r* informs the engine-man, upon his turning it, whether the pumps work properly. The pipe *a* communicates with the tender, and the pipe *b* with the boiler. It will be observed, that there are two valves in the pipe *b*, which make the separation of the boiler from the body of the pump more complete. Conical valves are inconvenient, on account of their being liable to get out of order, and they often require repairs; they are, also, more difficult of construction, and are easily displaced. The ball-valves are preferable.

It is important that the feed-pumps should carry the water to a certain part of the boiler. It is generally introduced at the middle of the cylindric portion, but in Stephenson's new engines the water is taken to the part surrounding the fire-box, where the ebullition acquires its greatest intensity, and the large amount of steam prevents the plates of the furnace from being constantly in contact with water. It is on this account that Stephenson has thought proper to introduce the supply at this part.

Mr. Cave's feed-pump (fig. 25) differs but little from the conical valve-pumps. The casing of this valve rests upon a circular stand. It is directed by a rod *t* moving in a collar, *m*. The plunger *p*, which is formed of cast iron, is hollow, and runs along the sides of the stuffing-box *ss* during the action of suction and compressing. The suction movement

opens the valve *c* and shuts *e*, and the compression shuts the former valve and opens the latter. The movement is communicated to the plunger by an iron rod, which is connected with the head of the ball *b*, the nut of which, *e*, is let into the casting. There is a cover above each valve, near the collar or guide, which can be lifted up in case they get out of order, or whenever required for the purposes of inspection.

27. *On Steam Pipes: on the Distribution and the Escape of the Steam.* — The steam is passed off at the upper part of the boiler, and there is a dome on the top, either at the fore or hind part of the boiler, and a safety-valve is sometimes placed over it; the steam which passes within this dome contains fewer particles of water in suspension by the ebullition than that in the steam-chamber. The steam-entrance is situated in this dome, as shown in fig. 26, and which is effected by the pipe *a*.*

Fig. 27, (plate 19) describes another form of dome, and shows the commencement of the horizontal steam pipe *b*; the steam passes directly into two pipes *c*, represented in fig. 28, which conduct it to each of the cylinders in the box where the slides move. These steam-chests are placed in communication with the cylinders, on one side or the other of the pistons, by the alternate movement of the slides. The pipe *g*, which is called the blast-pipe, (see figs. 10 and 11,) communicates with the centre steam-port, and the steam is thus passed from the cylinders into the chimney.

These, then, are the points of entrance and departure of the steam. There is a small double pipe at the lower part of the breeches pipe *d*, fig. 13, which conducts the waste steam to

* Great inconvenience arises from the water being drawn into the steam-pipe, as it is incompressible; and the pressure of the piston, in its backward-and-forward course, tends to occasion rupture. The amount of priming is now much diminished by increasing the size of the steam-chamber, as the renewal of steam is less abrupt, and causes less agitation in the water. We have described another mode of preventing the water getting into the steam-pipe in another place, which consists of forming a sort of border at the mouth of the steam-entrance.

the escapement-pipe; it is employed to let off the water arising from condensation, which collects in the cylinders, and in the pipe we have just been describing. Notwithstanding, the water can only get there by the action of the piston, a rupture may be the result, however trifling the velocity of the latter. Preference should therefore be given to cocks placed beneath the ends of the cylinders, such as those employed by Sharpe and Roberts.

Instead of passing the steam-pipe down the boiler longitudinally, the steam-entrance is placed near the chimney in new engines, (see fig. 29.) The advantages of this plan are so great as to cause it to be generally adopted. There is, in these instances, an economy of pipe and of space in the steam-chamber; they are also less liable to be deranged by the variation of the temperature. The principal reason for adopting this plan is on account of the friction which the steam experiences, by the former system, from the great length of the pipe. Again, it sometimes happens that the steam-pipe becomes covered with water; from the engine-man allowing the water to rise above its proper level, and the joints not being always sufficiently close, the water finds its way through them, and then passes along with the steam. There are two steam-entrances in some engines, one over the fire-box, and another near the chimney, both being connected with the same pipe.

The pipes of distribution are formed of copper, of about one-seventh of an inch in thickness.

They have to support a considerable pressure, and the steam acts upon them with all its force at the period of stopping an engine. This pressure is also exercised in a similar manner on the exterior; they therefore require to be made of a suitable shape to withstand this pressure.

They are fastened by lugs to the plates of the smoke-box and furnace; the joint which connects the large pipe with the smaller ones affords a means of taking them to pieces when the boiler requires cleansing, and access is required to the pipes.

The steam-pipe is laid with an inclination, to allow the priming-water to run out, a cock being placed at the extremity. The sudden movements which the pipes are subjected to, the rapid changes of temperature, and the difference in the expansion of iron and copper, soon affect them. The steam-pipe is fixed to the boiler by means of a stuffing-box d' (fig. 28.) The diameter of the steam-pipes of distribution is $3\frac{3}{4}$ inches within, with a thickness of 1-5th of an inch; they should be, and generally are, made of greater substance than the ports.*

28. *On Regulators.*—The regulator is placed in front of the fire-box, by means of which the fireman opens or closes the entrance to the steam, and increases or diminishes the size of the passage.

The plan of this contrivance varies according to the manufacturer's views, but it is very important that the engineman should be perfectly acquainted with the forms of these regulators, that he may use them properly.

Stephenson makes his regulators rotative, (fig. 30, plate 20) in which he is followed by many other engineers. Fig. 28 shows the situation and the general view of this regulator; a handle, M, communicates a rotative motion to an axis, *a*, passing through a stuffing-box, and fixed by means of a centre-pin, I. The axle communicates its motion to a brass plate composed of two triangles, *c c* and *c'c'*, rubbing against the cast-iron box, and following the circular face *x x*. This plate may be moved over the open spaces *b b'*, enclosing them completely, or can leave them totally uncovered, or partly on one and partly on the other, as the slightest effort of the engineman, by means of the handle, operates upon it.

This regulator affords a tolerably large area for the passage of the steam, even for a slow course, except during the short periods that the plate is passing over the solid parts, *p p p'p'*.

* The expansion of copper from 0 to 100° of the centigrade thermometer is about $\frac{1}{588}$ of its length; and iron is $\frac{1}{910}$, that is to say, they bear the same proportion as 1 and 0·64. The relative expansion of iron and of copper, taken in round numbers, may be stated at 5 to 3.

The pressure existing in the chamber B and in the pipe *b*, fig. 28, is regulated by the velocity of its escape. It is equal to that generated under the pressure of the boiler, when the entire section of the regulator is open to the passage of the steam, since the area of this opening is the same as that of the pipe B. It is necessary to open the regulator, to overcome the friction arising from the difference of the two pressures. A graduated circle on the outside exhibits the degree of opening of the regulator, to which the engine-driver should pay the greatest attention.

Tayler employs a regulator very like Stephenson's in principle, but the general arrangement is different. It is shown in fig. 31. The steam-entrance is near the chimney. The casing on which the plates of distribution rub is made of the form shown at *a a'*—*b b'*. The rotative movement is acquired from the axis. The small pins *x x*, (in the front view) serve as stops to the turning plate, both when it opens and when it closes the orifice of passage.

The apparatus employed by Bury in his four-wheeled engine, "La Seine," consists of a simple cock with two openings, fig. 32. The opening *a* communicates with the steam-entrance pipe; the opening *b* communicates with the steam-pipe of distribution. The stuffing-box *s* is placed on the casing of the boiler *p p*. It may be easily conceived that the friction is considerable in a regulator of this description, and that it requires expensive turning and workmanship. This description of regulator also soon becomes deranged, in consequence of the unequal expansion to which any contrivance is necessarily subjected when unequally placed. The above engine, however, is the oldest on the St. Germain railway, and the regulator has never been repaired, which no doubt is attributable to its being the only one that can be readily greased.

Bury has also employed another regulator in some of his engines, the principle and application of which require modifying. The general view is given in fig. 27, and the section in fig. 33, plate 21.

The pipe *a* is the steam-entrance; *b*, the pipe of distribution; *c*, a pipe which is situated on the casing of the boiler; *k* is a brass cylindric piece, which is placed on *k'*, as shown in the diagrams. A helix formed with a groove *x*, is connected with the gudgeon; upon the engineman imparting a rotative motion to the axle *c*, by means of the handle *m*, the helix follows the gudgeon, and gives a rectilinear motion to the piece *k*. (*See* details of the piece *k*.)

The connexion of the piece *k* with the axle is effected by the help of two iron pins, which are fixed on the former, and which slide in two grooves connected with the axle; the latter can only take a rotative movement, but the piece *k* is guided by the pins, which cause it to slide along the axle, and thus it opens and shuts the communication with the pipes *a* and *b*.

This regulator requires cleaning and greasing very often, which is unfortunately a long and difficult operation, since a man is forced to get into the boiler and raise the gudgeon, in order to take out the piece *k*; and unless it is properly greased the friction is very great—first, at the circumference of the piece *k*, but more especially in the groove *x*, and at the axle, wherefore it is almost impossible to manage it. It is, therefore, necessary to reject this apparatus, from the inconveniences attending it, although the combination is certainly ingenious.

The piece *k* does not always fit the circumference well, and the steam gets into the port *c*, when the regulator has a great tendency to shut of itself, which obliges the driver to keep a constant hold of the handle.

The regulator of the "New Jackson," again, is of a different construction (*see* fig. 34): *m* is the handle, and *a* is the fixed point of rotation, which imparts the shifting movement to the frame *g g'* by help of the button *c*; the cylinder *e e'*, does not touch the sides of the cylinder *f* when it is lifted up, and the steam can, therefore, enter by the holes *i* and pass into the pipe of distribution. The pressure on both sides of the en-

trance *e e'*, is equal to that in the boiler. The conductor of the engine experiences very little resistance in opening and shutting the regulator, which is one of the greatest advantages connected with it. Another not less important point is, that the regulator can be opened with the least movement of the lever *m*, which is not the case with Stephenson's regulators; in fact, the size of the steam-entrance can be changed to whatever is desired, and to any extent that the steam-passage will afford.

This regulator, however, has the inconvenience of sometimes allowing the steam to escape when it is shut, which results from the unequal expansion of the bodies, the steam introducing itself through the spaces *e*, and by *e'*.

There are several other regulators employed. Some are formed with hatches (*see* fig. 35); others have a moveable valve, which works by the aid of a screw placed at the extremity of a rod, near the hand of the engineman.

The effects of the regulator require to be perfectly understood. When it is opened, the steam acquires a velocity proportionate to the difference between the pressure in the boiler and that in the steam-pipes. Upon the opening being reduced, the volume of steam escaping is also reduced. As the regulator continues to be opened, so the force of the steam passing to the cylinders continues to be reduced; and it is by this that the velocity and weight of the train are regulated according to the nature of the work. There is evidently an advantage in increasing the diameter of the pipes of distribution, that the driver may be more completely master of the effect, which is limited to the possibility of supplying sufficient steam to render the strength in the cylinders equal to that in the boiler.

29. *On the Steam-Chests and Cylinders.*—When the regulator is open, the steam passes into the cylinders through copper pipes, about $\frac{1}{8}$ of an inch in thickness. The cylinders are of cast-iron, about $\frac{1}{11}$ of an inch in thickness. They are divided into several portions, as shown by the transverse and longitudinal sections (figs 37 and 38, plate 22).

The chamber B, situated at the upper part, is called the steam-chest or slide-box, and contains the steam-ports and slides C. The motive steam enters this box by the steam injection-pipe A, and it is enclosed on every side, the joints being properly stopped.

The steam-chest should be as large as possible, that the steam within it may be affected by the least velocity, and that it may not lose heat, and consequently strength. The upper part contains four apertures, called ports $e\,e'$—$g\,g'$, two of which, $e\,e'$, form a communication between the steam-chest and the inside of the cylinder; and the two others, $g\,g'$, communicate with the apertures of escapement Q, by means of the inside of the slides. Fig. 36 gives the plan of a cylinder; one of the slides is shown on one side, and the other is removed, the apertures $e'g'$ being left exposed; $a\,a'$ are two elliptic openings, for the purpose of allowing the position of the slides being seen in connexion with the ports when the distribution of steam is regulated. The cover is secured to the cylinder by screws, the worms of which are formed in the substance of the casting.

The slides are formed either of brass or cast-iron, and an alternating movement is communicated to them by means of a rod passing through a stuffing-box, *b*. This rod is fastened to the slides by means of rectangular iron fillets, $d\,d\,d'd'$. It is connected to the first lug by a screw and worm; the second slide is secured to the first by a short cross-rod, and it screws at each end into the fillets by screw-boxes, to prevent their loosening. The two last screws are placed, one upon the right, and the other upon the left, and afford a means of bringing the slides nearer each other, or of separating them, and keeping them at whatever distances may be required. It will, therefore, be perceived that the appendages are independent of the slides, *i. e.*, they do not form one body with those operating upon the slides from the pressure of the steam. It is for the same reason that, in steam-chests with three ports instead of four, the whole are placed at the end, in advance of

the slide-box: the slide-rods are also made tolerably long, so that, in case of the slides wearing out, the rods, from their length, will have a tendency to bend, and keep the valves close.

The alternating movement of the slides introduces the steam by the ports, either upon one side or the other of the pistons. The dimensions of the ports vary according to the engines; their section is generally equal to $\frac{1}{10}$ the surface of the piston. The pressure on the slides per square inch, at the surface of the interior of the box, is equal to that which acts on the pistons, so that the slides adhere closely to the plates upon which they are placed. The parts subjected to friction are planed, and the surfaces tempered, so that they invariably wear out the slides without being affected. The replacement of the slides is neither so expensive, nor does it occupy the time that would be required to replace the top of the cylinder. The cylinders in which the motion originates are formed of cast-iron, about $\frac{3}{4}$ of an inch in thickness, and from 12 to 13 inches interior diameter, highly polished to receive the turned piston.

The joints of the pipes with the cylinders are cast with flanges, and cotton, lead, or red mastic, is interposed between to render them close.

The cylinders are shut on one side by cast-metal covers, which can be readily removed when the pistons require to be repaired. A small hole is made in the centre of each cover, to receive the grease-box, which communicates with the interior of the cylinder. The other end is closed by another cover, very similar, but of less diameter than the other, since it is unnecessary to provide for the piston passing out at this end.

There are only three ports in many engines instead of four—two for the introduction of the steam, and one for the passing it off. Fig. 39, plate 23, shows a section of Tayler's cylinder, having one slide and three ports. The inconvenience of having only three apertures is, that the steam-passages are

necessarily much longer; and as the steam introduced at each stroke of the piston passes by the escapement under the slide, the quantity lost is more considerable. It is, therefore, disadvantageous on this account, but the surface in friction is considerably less. The slide-rod in this cylinder is directed by two stuffing-boxes, which is different from the general mode. The little apparatus *r*, in the form of a reverse-cock, is for the purpose of introducing oil into the cylinder. It can also be turned, to allow the water arising from condensation or otherwise to escape. It is very seldom used, the position being bad; it should be at the lower port of the cylinder. Some manufacturers practise a better method with their cylinders; the sides of the cover, instead of being made vertical, present two inclinations externally, one upon the side of the port, the other at the lower part. A cock communicates with the latter, which empties the cylinders of any water they may contain. This plan of ridding them of water, however, is seldom employed, as the strokes of the piston are generally sufficient to drive it away through the ports, whence it passes by the blast-pipe into the chimney, or it collects at the lower port of the drain-pipe, which is furnished with a cock. If the ports were closed too soon by the pistons they would not be able to carry off this water, and the fluid being almost incompressible, the piston would experience a resistance in striking it similar to that in striking a metallic mass, which would produce a rupture of the principal parts. The stuffing-box *s* also presents a different construction to that which is generally adopted; fig. 39 gives longitudinal and transverse sections of it. The box *a* possesses the advantage of holding oil, and of keeping the piston-rod constantly greased during its movements. This box forms at the same time a stuffing-box, on entering the polished cylinder *c*. Another stuffing-box is connected by the two collars *a* and *h*, and the cylinder cover *d* merely serves to protect the interior of the grease-box from dust and other extraneous matter introducing itself. The system of distribution practised by Sharpe and Roberts ap-

pears to possess some advantages. The steam-chest is cylindrical, and contains a hollow piston, formed of copper, which is worked by a rod, like an ordinary slide. There are two compartments in this cylinder; the outer one receives the steam by the circular holes *o o*, and introduces it into the cylinders by the rectangular holes *g g g' g'*, being connected in its course with the port communicating with the cylinder; the steam then passes out of the cylinder, when the same port is again uncovered, being passed along the interior compartment directly into the escape pipe *b*. This plan allows of the apertures of admission and escape being larger than usual, and the action of the distribution of the steam is free from pressure. The wear of the copper cylinder is the only thing to be feared, which would occasion a loss of steam.

30. *On Pistons.*—The pistons which work in motive cylinders are of various construction.

Fig. 41 (plate 25) is a section and front view of the piston employed in Stephenson's. The whole of it is formed of brass; it consists of a plate formed solid in the middle, with three lugs radiating from it, and placed at equal distances from each other. Another circular plate, *d*, is fixed to the plate *b* at the other side of the piston, and nearly covers it, forming a body with the other by means of bolts let into holes left in the piece *b*. The plates *a* and *b* are turned of nearly equal diameter as the cylinder, yet so that they are quite clear of each other. The circles *f*, which are the only portions that rub against the sides of the cylinders, are placed between the plates; they are 4-10ths of an inch in thickness, and are composed of several segments, but in such a manner as to break joint with each other. They are turned internally and externally, so that they fit the sides of the cylinder exactly, one upon the other. These joints possess a certain degree of elasticity to the circles, and after a certain period the latter extend and press against the cylinder, so as to wear it out. This plan, therefore, soon becomes ineffective. Springs are employed to remedy this defect; they are three in number,

r r r, and each act on the circles at two points. Three screw-bolts, *t t t*, pass through the centre of these springs, and secure them to the central boss of the piston. As the circles become worn from the effects of friction, it is merely necessary to turn the bolts, which project a little beyond the screw-boxes, until the springs are suitably arranged, and at the same time to tighten the screw-nuts, to prevent the bolts returning. Access to the interior of the piston is readily obtained, by unscrewing the bolts of the cover and taking it off.

Fig. 42 gives the section of another piston employed by Stephenson, which does not differ much from the one just described; it has three springs, like the former, which are placed in the positions *r' r'' r''*.

The pistons are frequently furnished with two or more circles, formed of brass or iron, of about one inch in thickness, and divided into three or four segments, with wedges placed between them, which are pressed outwards by the springs, and tighten the segments on the cylinders. Jackson follows this method, (*see* fig. 43). The packing is composed of two brass circles, *g g'*, the same as Stephenson's pistons, but they are not the same size throughout. The tightening wedge, which is formed of iron or brass, is placed at the largest part, and affords the means of enlarging the circle, to make it fit the interior of the cylinder. The flat springs *r r* serve to hold them in the cavities *t t*. The springs rest on the brass lugs *o o o o* in the piston. The pressure acts upon the wedges, as in Stephenson's pistons. The wedges and springs of two layers of packing break joint with each other. The utility of the wedges is not felt until the packing begins to wear. When the apparatus is first put together, the wedges scarcely enter the cavities prepared for them, and the circles fit the surface of the cylinder exactly. Pistons of this construction are subject to an inconvenience which those with springs, without wedges, are not, which occurs when the segments are worn: the wedges rub the sides of the cylinder, and at length form grooves along it. The system of seg-

ments and springs, without tightening wedges, therefore, appears to be preferable, unless the defects of the latter can be remedied.

Jackson has also employed a metallic piston with hemp packing, the vertical and horizontal views of which are given in fig. 44 (plate 26.) It is composed of two castings, which enter one in the other at *a a*—*d d*. The packing is placed in the space between them, consisting of copper or iron circles, formed in segments, which form a spring, and the joints of which are oblique. The inferior part is joined to the other by the means of three bolts, *b b b*, and copper nuts. There is a nut, *x*, tapped on the inside to receive the end of the piston-rod; the remaining portion of the piston is also tapped, and finished in a conical shape, where the top of the piston enters. The circular springs are packed and replaced with hemp as they wear. These pistons, however, frequently require to be unmounted, and the hemp replaced, as it does not preserve its elasticity long.

The pistons at Haigh Foundry (fig. 45) are made similar to Stephenson's, but the discs and circles are formed of brass instead of copper; further, instead of having four springs each, there is but one, upon which a wedge operates. The rod is fixed to the piston by means of a key. The bolt *b* performs the tightening and easing by means of a double screw-nut. The four lugs *o o o o* receive bolts, which serve to fasten the upper and lower plates together. The thickness of the circle is unequal, like the first piston of Jackson, and the wedge is placed in the thickest part, as shown in the figure.

The circles forming the packing of the Haigh Foundry piston are made of brass. It is found that, when the part in connexion with the wedge is of too great thickness, the thinner part shrinks in, and is no longer in contact with the sides of the cylinder. One great improvement in this piston consists in the strength of the screw pressing the wedge, which, being placed on a steel circle, *c*, concentric, and within the brass packing, distributes the force uniformly throughout

the circumference. In Jackson's piston, on the contrary, the point of strength being on the centre of the piston only, it results that, independent of the effort of resistance produced by the wedges, there is a pressure in the direction of the screws, which creates great friction on this side of the brass circles, while the parts required to be in close contact barely touch. The inequality of the friction is mainly attributable to this defect.

Tayler saw the necessity of equalizing this pressure before the improvements made at the Haigh Foundry; instead of one wedge, however, he has employed four on the circumference.

Fig. 46 gives two sections of the piston used by Bury, the packing being supposed to have been taken off, being exactly similar to the preceding. There are three springs, which are adjusted by screw-nuts, supported on the sockets *a* . . . *b*. Three bolts, passing through the lugs *o o o*, secure the upper part to the lower.

Hemp-packing is very generally used in the pistons of stationary engines instead of metallic; but this plan is much inferior to the latter, as it requires to be frequently renewed. The pressure, moreover, is very unequal, in consequence of the great pressure to which the tow is necessarily subjected, in order to make the piston tight. This plan is, therefore, quite inadmissible with a locomotive engine, on account of the great velocity of the stroke of the piston.

The stroke of the piston varies, according to the purpose of the engine, from 15 to 18 inches. The action of the steam in the cylinder is exactly the same in stationary machines; but the cylinders, instead of being placed horizontally, are generally vertical. The horizontal position is disadvantageous, in consequence of the unequal action of the piston on the cylinder, from the gravitating influence of piston and piston-rod. The wear is, therefore, greater on one side than the other, and the rod is submitted to a flexure, which is highly injurious. The pistons of locomotive engines being very small and light, the wear is tolerably equal; but those of stationary engines

being generally of larger diameter, this action is very destructive.

31. *On Piston-Rods.*—The piston-rods are about 1¾ inches in diameter; they are increased conically at the extremity to 2 inches diameter, through which enlargement the keys of attachment pass. The keys are about 4-10ths of an inch in width, and fix the pistons to the rods in such a manner as to prevent any movement. The other end of each rod passes through the stuffing-box placed in the cover of the cylinder, which we have already referred to. The rod is turned in steel, and polished, so as to present the smallest amount of friction in the stuffing-box. There is a collar attached to each rod, to receive the rod of one of the feed-pumps, which thus partakes of the movement of the piston. The connexion of the two rods of the pistons and of the feed-pumps is given in fig. 48 (plate 28.) The collar is enabled to take different positions, to support and facilitate the work of the plunger, according to the position of the barrel of the pump.

32. *Heads connecting the Piston-Rods with the Connecting-Rods.*—One end of each piston-rod is fixed to the piston; the other, J, is made with a double head, *t t*, with a space between them, which receives the head of the connecting-rod. They are connected by a wrought-iron axle, *a*, terminated by two small steel guides, furnished with external flanges, and disposed between two steel slides with grooves, *d d'*, also fixed to the larger weigh-bars by means of bolts. There are two guides for each piston, which, with the slides, serve to maintain the rod constantly in the line of the axis of the cylinder. J is the piston-rod; *i*, the piston of the feed-pump. There are holes in the guides at *h* and *h'*, which are intended to receive the axles *a a*. The head of the connecting-rod, by which the motion is transmitted, is placed at *a'*. The guides are grooved to fit, and the flanges prevent their moving out of position. The surfaces on which they rub are also well greased; so that the piston-rods are directed without much loss of force. Fig. 48[3] gives the details of these slides.

The motion of the rod is sometimes directed in another manner. The axle *a* is terminated at each extremity by a rectangular steel eye, which is enclosed by two steel bars, rendered perfectly rigid and horizontal; the axis *a* is thus directed by sliding between the two bars.

There are other modes employed by different makers, but they all partake of the arrangement shown in fig. 48 *bis*.

33. *On Connecting-Rods.*—The connecting-rod is at present placed with the piston-rod on one side, and the cranked axle on the other (fig. 49.) The heads of the connecting and piston-rods are of similar construction, but the latter is formed double, as shown in fig. 48. The shape of these heads is nearly the same in all engines. Fig. 49 is a section of a connecting-rod, taken in the longitudinal direction of the engine.

The directing axle *a* is sometimes made spherical in the middle, (*see* fig. 53, plate 29,) which allows the movement to take any direction required. This part is subjected to much torsion, any irregularities in laying the way being directly felt by the cranked axle; the eye-piece *o* rubs on this part; *b* is a brass carriage formed in two parts, intended to reduce the friction. An iron strap, *c*, joins the upper part of the carriage, which is secured to the connecting-rod by means of gibbs and collars, *d*, in the ordinary manner. The wedge-shaped piece *e* serves to bring the two parts of the carriage together when they begin to wear: a void or space is left at *i* for this purpose. The carriage projects beyond the two faces of the head, and is furnished with external flanges, which prevent its becoming displaced. Two holes are formed in the head of the connecting-rod at *g g*, which receive small tightening screws, that fix the keys when they reach their places.

After the tightening-keys are secured by the screws *g g*, they are each split along the middle from the end, and a wedge is driven in, which separates them; they are further held by pins, *h*.

Fig. 50 shows another mode of fastening the head of the connecting-rod, with a grease-box, *k*. The collars are drawn

closer as they wear by means of the key *e*, which tightens the gibb *d*, lowers the stirrup *c*, and again tightens the upper part of the collar *b*.

This method possesses the inconvenience of removing the centre *o* from its place, as the collars wear from the effects of friction. The same defect occurs with the head of the connecting-rod, fig. 49; the only difference is, that the connecting-rod, in this case, gets longer, while that described in fig. 50 becomes shorter. One advantage of the head of the connecting-rod, fig. 49, is, that the strap is fastened, independent of the keys which tighten the gland.

The joint of the piston-rod, with its head, is effected by means of a socket which it is keyed to, (*see* figs. 48 and 53.) The connecting-rod is placed at A. The tightening-bolts *g* act on the wedges, and prevent their getting out.

Fig. 51 gives the details of a tallow-box.

The pipe *t* is fixed with screws, and contains a cotton thread, which imbibes the oil from the bottom of the box, and conveys it by the syphon principle and capillary attraction to the parts requiring to be greased.

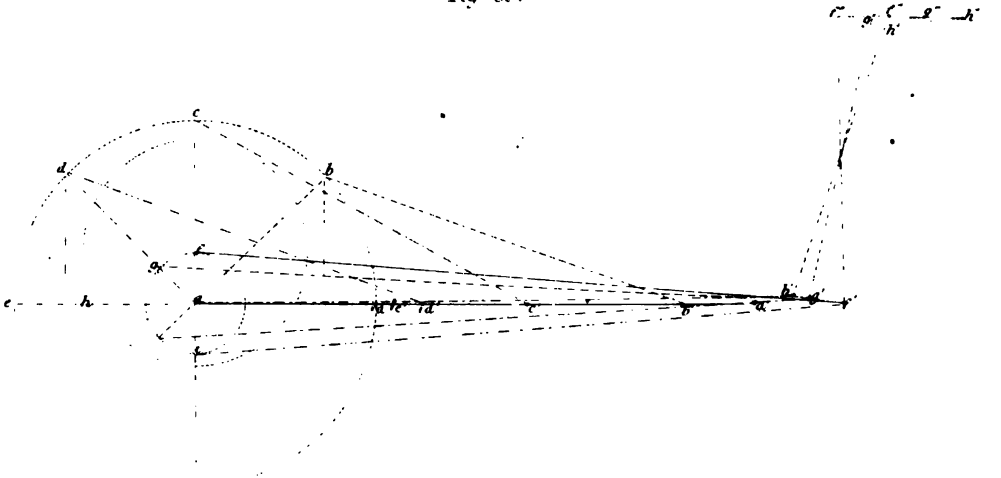
The head of the connecting-rod, which is fastened to the cranked axle, is formed after the following plan, *see* fig. 52 (plate 29). It differs but little from the other; but the means it affords of tightening the gland upon the axle is more certain and regular; the nut *b* is tightened, while the nut *b'* is loosened. The pressure exercised on the face of *a* is transmitted to *c*, which again forces the gland *b* still closer into the aperture intended to receive it, so that it closes upon the cranked axle from each side.

This system of keying is not, however, without inconvenience, as the diameter of the tapped parts becomes reduced to the thickness of the keys, and therefore they often break at this part. It is highly necessary to be careful in the use of screws.

It is important that the distance from axle to axle, of all the pieces employed in transmitting motion, be perfectly true and constant, since the manufacturers, in order to render their

Movements relating to the Piston & Slide Rods.

Fig 59.

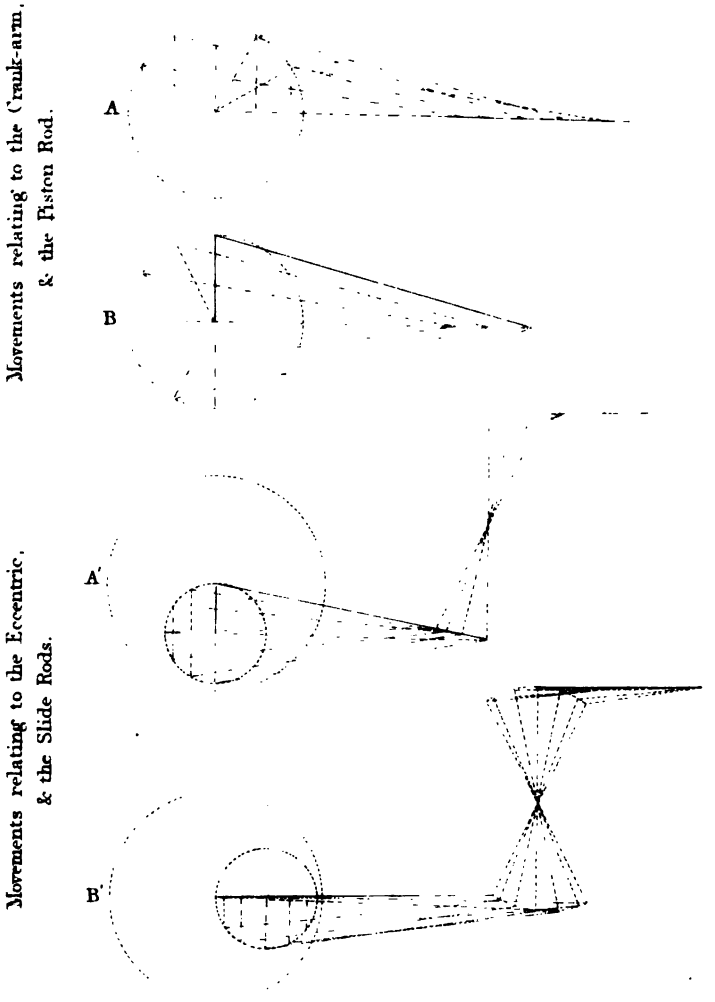


B.E.Davies fc.

Plate 33

Microfilm

Fig. 60.



B.R.Davies sc

Not U

Fig. 14.
Smoke Box.

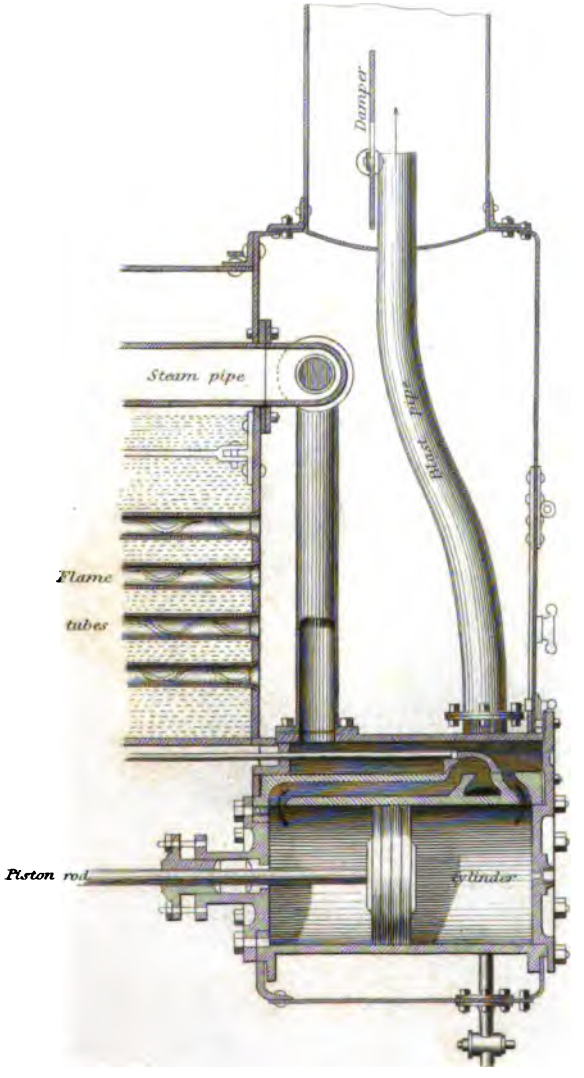


Fig. 15.
Diagram shewing the several appendages to the boiler together.

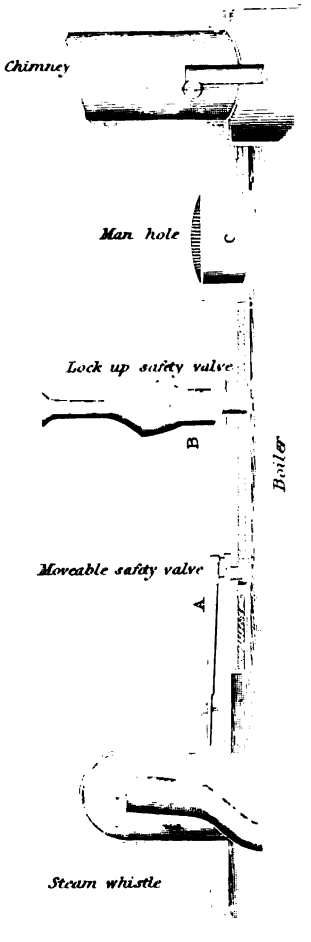
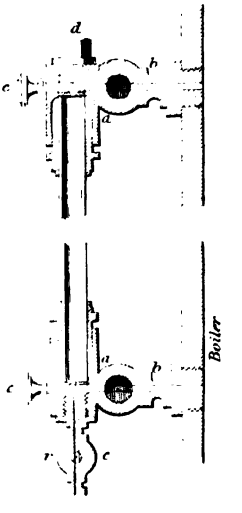


Fig. 16.
Water Gange.



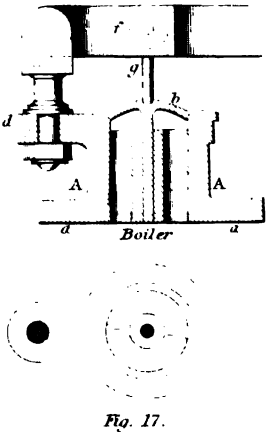


Fig. 17.
Moveable safety valve.

B. R. Davies fculp.

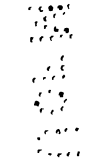


Fig. 18.
Moveable safety valve.

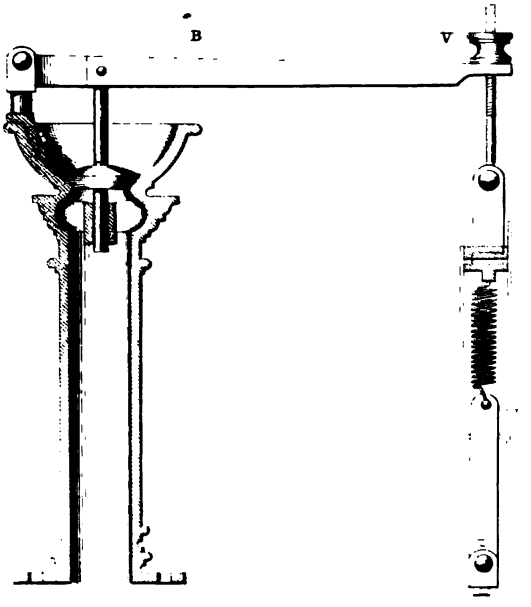
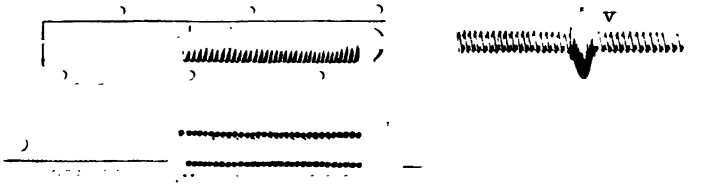


Fig 19
Details of spring



B. R. Davies, sculp.

Fig. 20.
Lock up safety valve formed of springs.

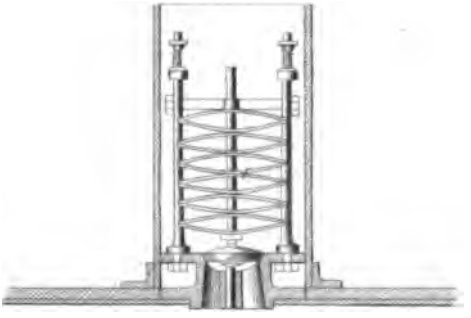
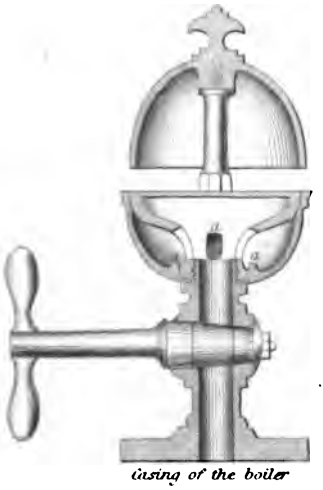
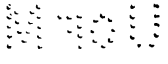


Fig. 21.
Steam whistle



casing of the boiler

B R Davies sculp.



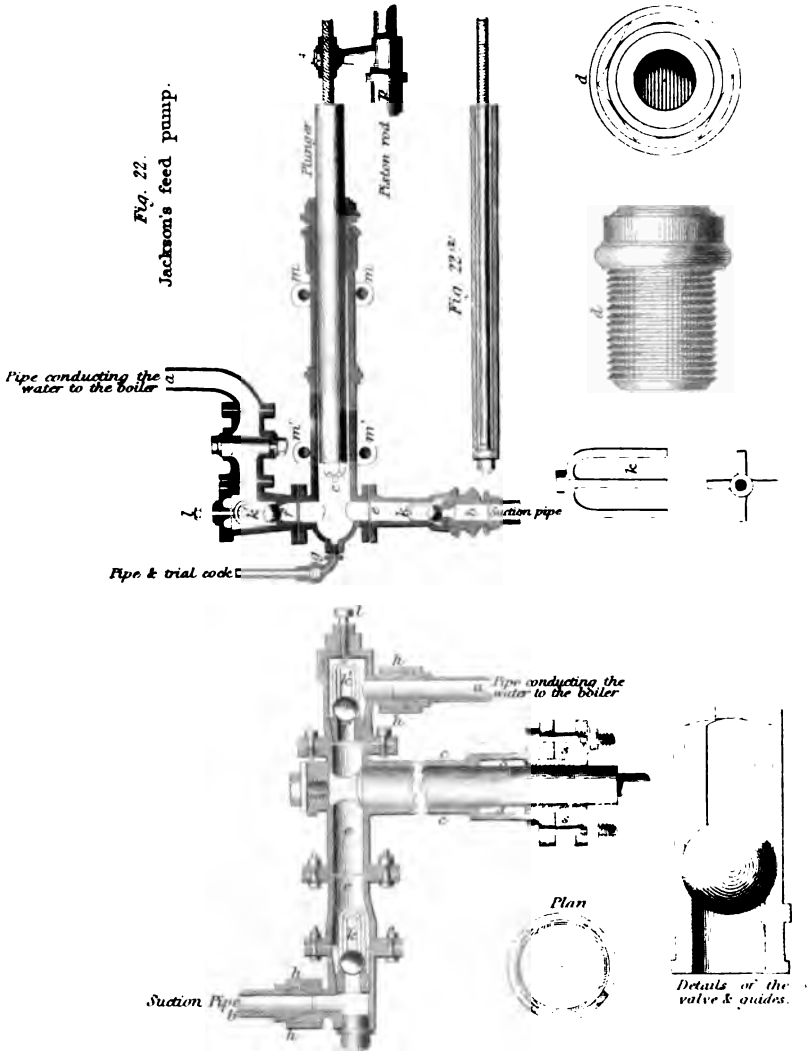


Fig. 23.
Stephenson's feed pump with bullet valve.

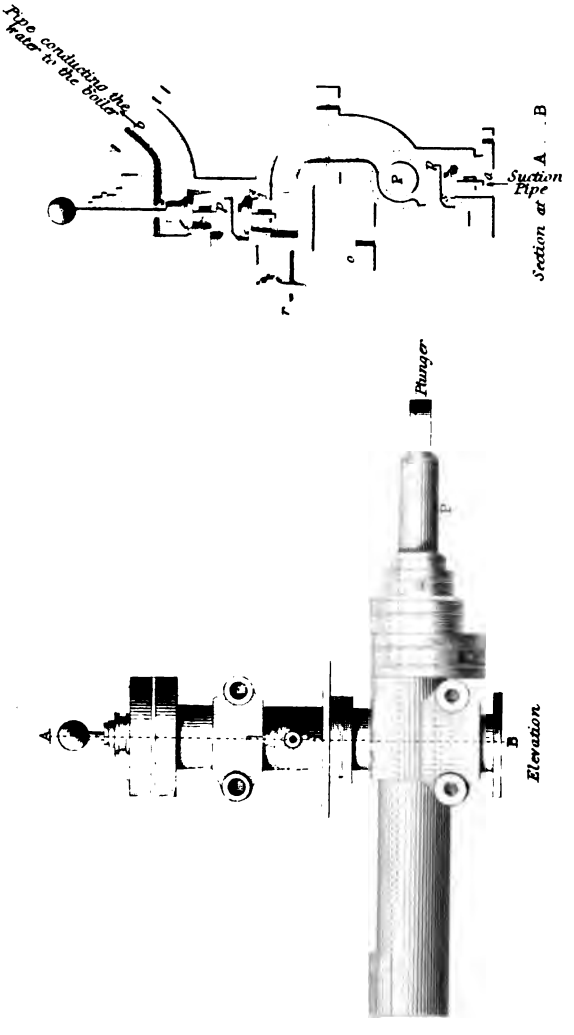
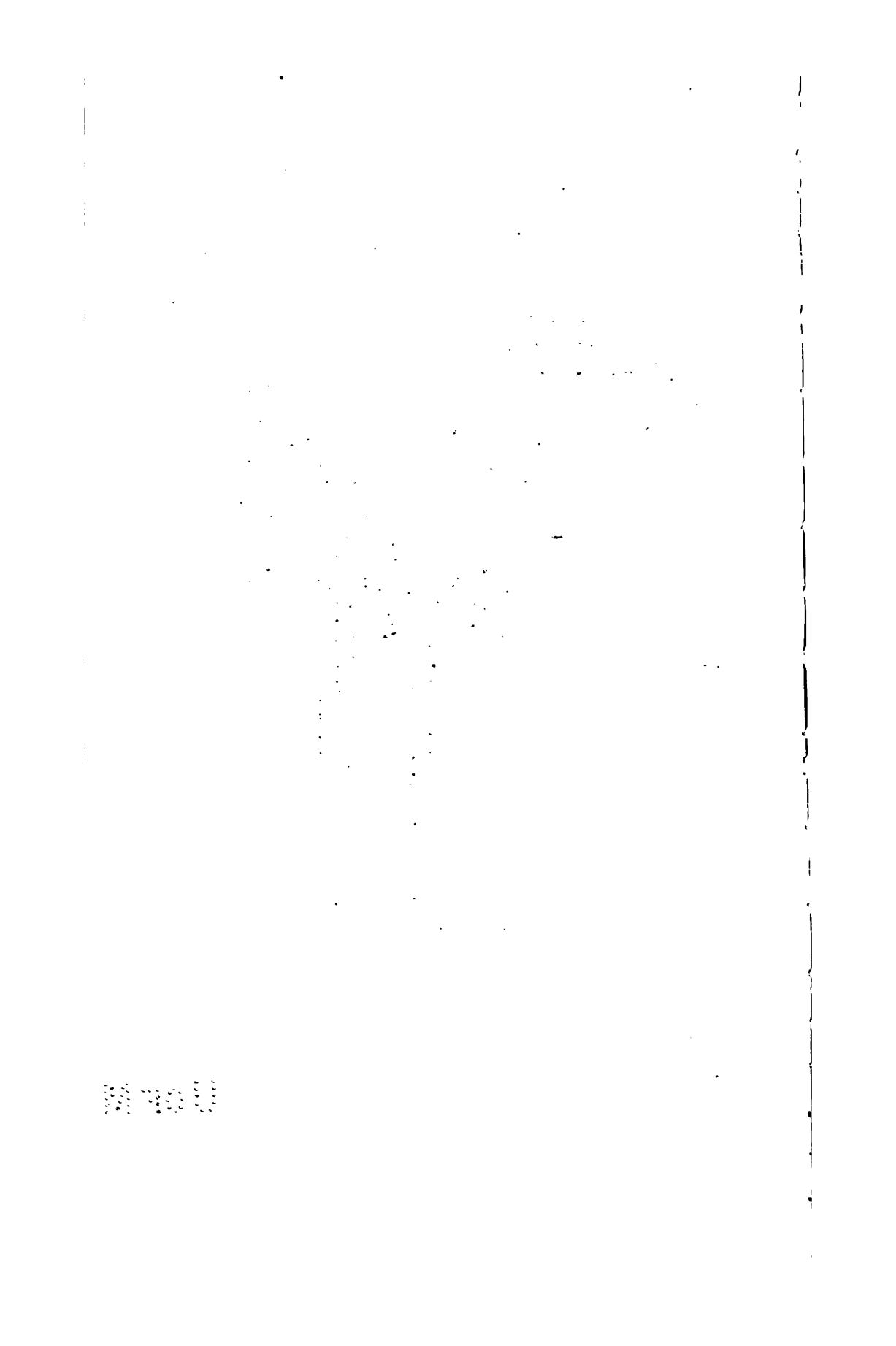


Fig. 24.
Bury's Feed Pump.

B.R.Davies Sculp.



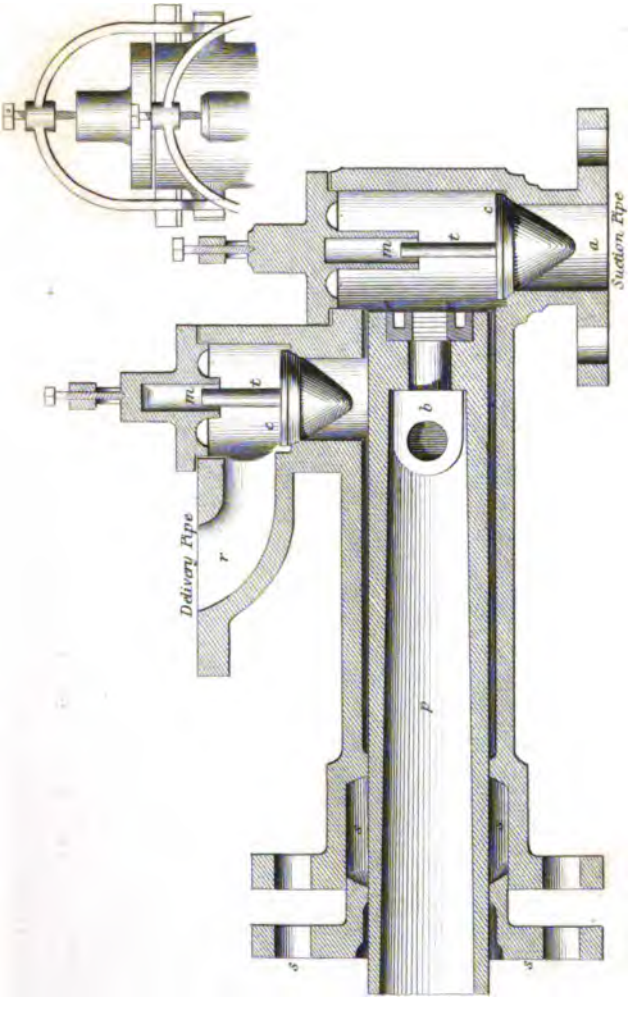


Fig. 25.
Cavé's Feed Pump.

Fig. 27.
Bury's Steam Entrance.

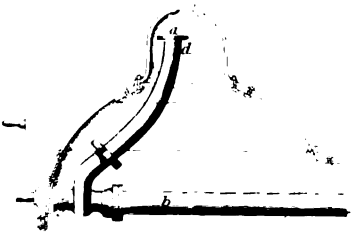


Fig. 26.
Jackson's Steam Entrance
and moveable safety valve.

Fig. 29.
A Steam Entrance
placed next the chimney.

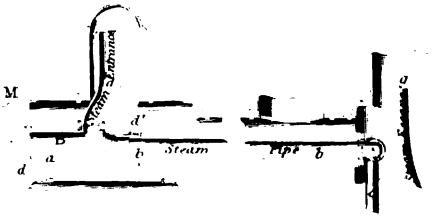
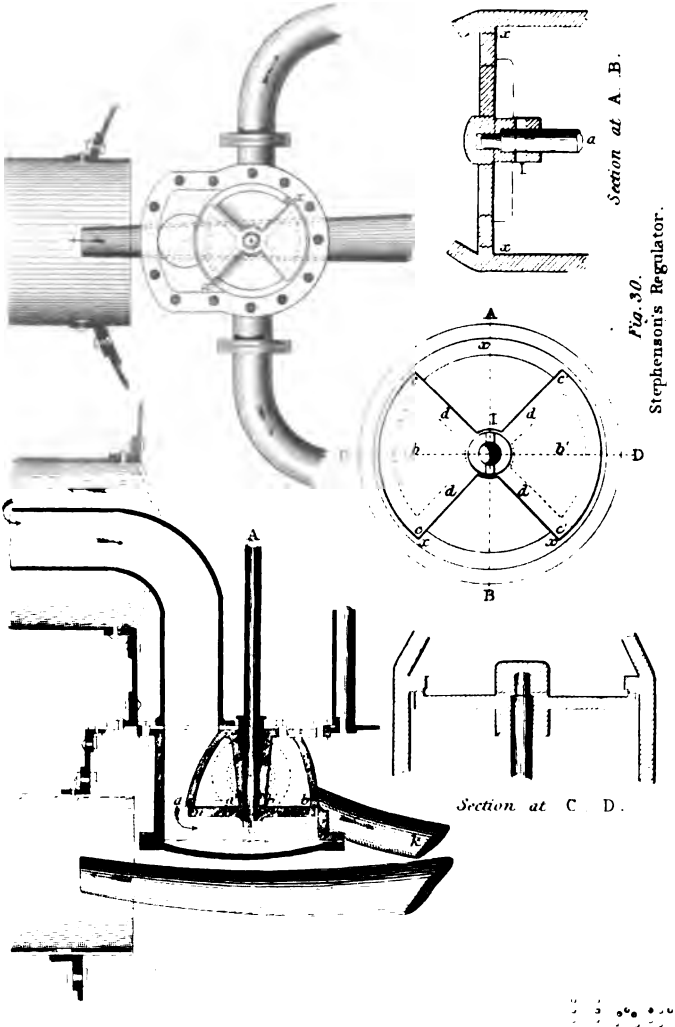


Fig. 28
Section shewing the distribution of the steam.

B R Davies sculp.

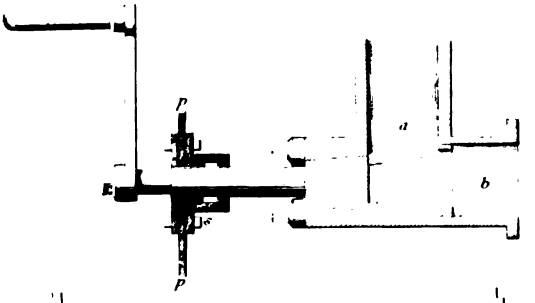
MAU

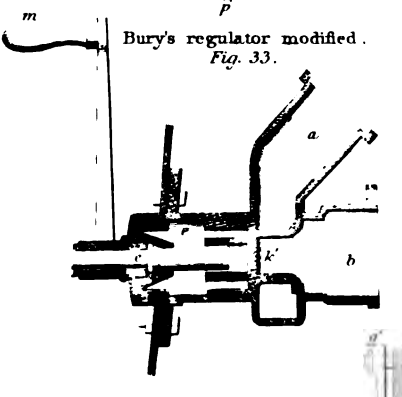
Distribution of Steam and Cylinders.



B. R. Davies sculp

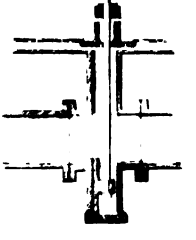
Fig. 32.
Bury's regulator. (La Seine.)





Bury's regulator modified.
Fig. 33.

Fig. 35.



Regulator with hatch and screw.

Details of the piece K.

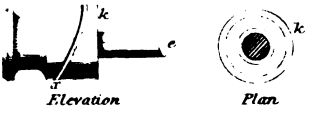
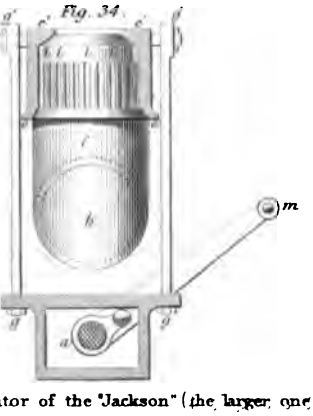


Fig. 34.



New Regulator of the "Jackson" (the larger one.)

Plan & Section of Jackson's cylinder (Denys Papin.)

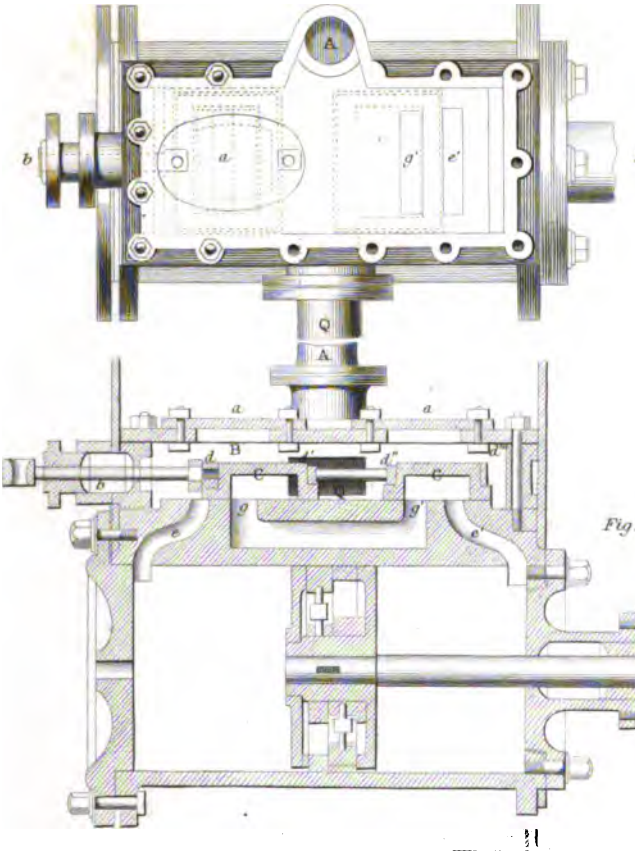


Fig. 36.

Fig. 37.

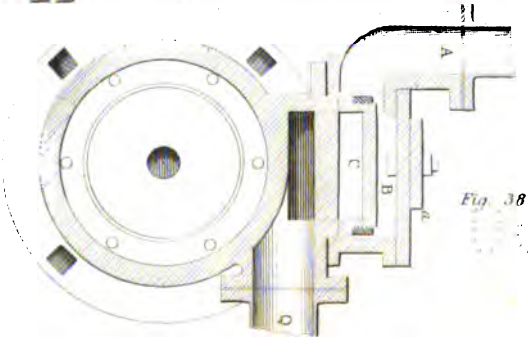


Fig. 38.

B. R. Davies sculp

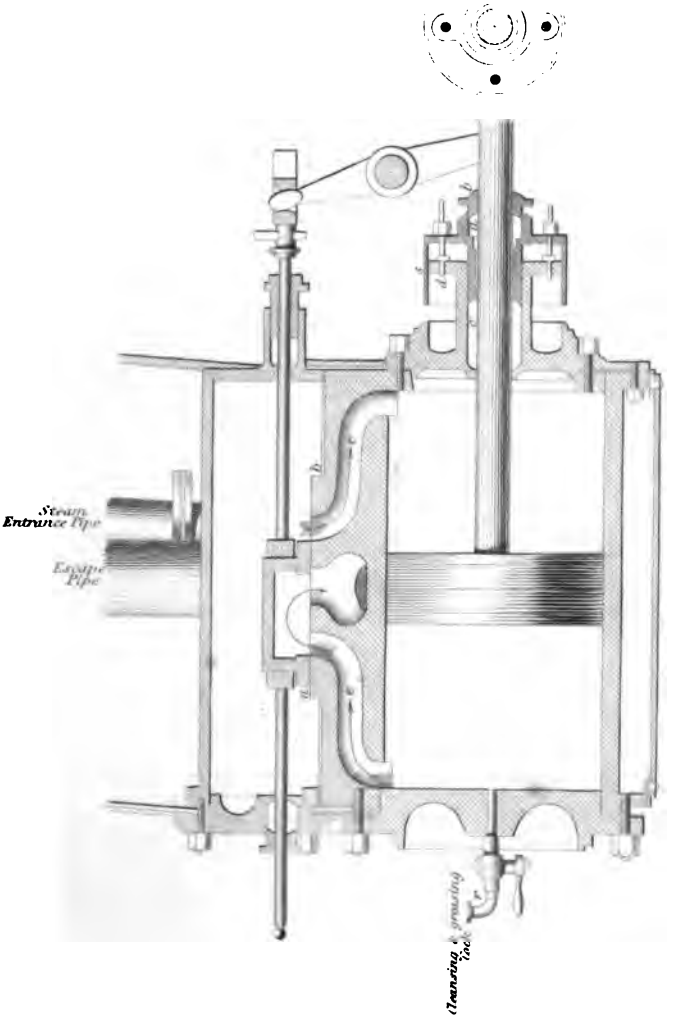
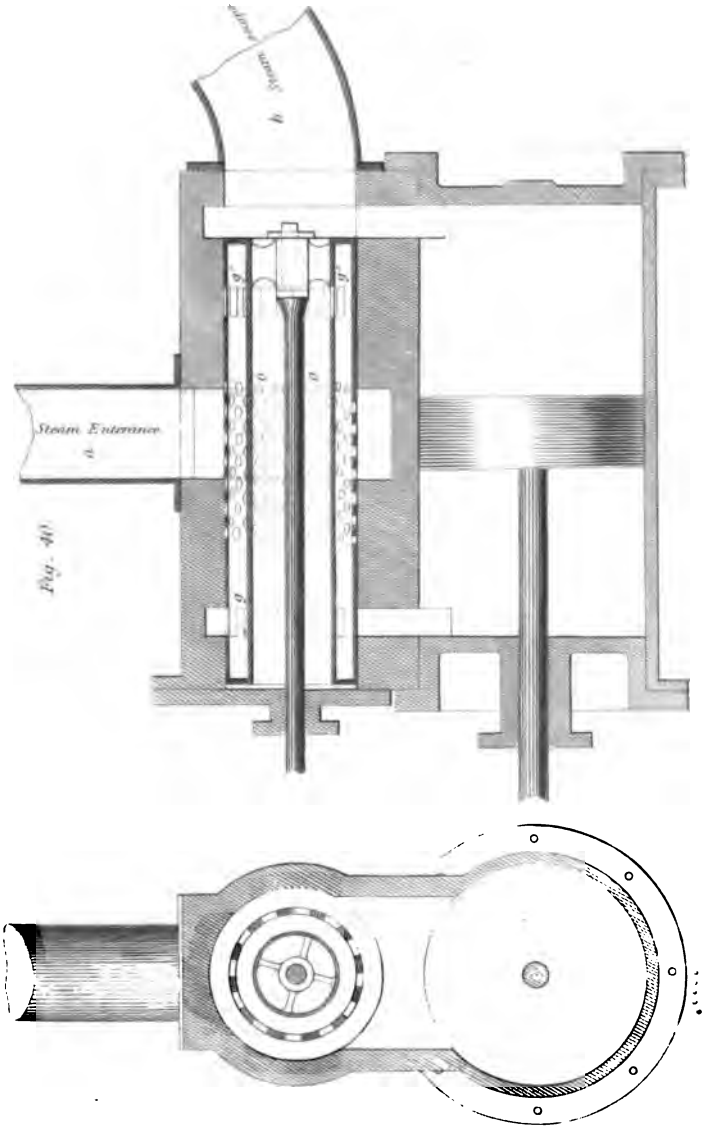


Fig. XV
Cylinder of Taylor's Locomotive Engine.

B.R.Davies sculp.

Plate 24

Sharp & Roberts Distribution.



B.R.Davies fe

Fig. 43.
Piston employed by Jackson.

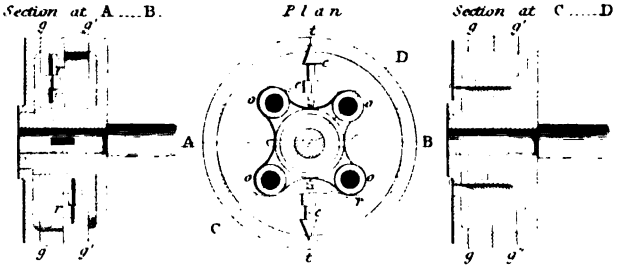


Fig. 42.

Pistons employed by Stephenson.

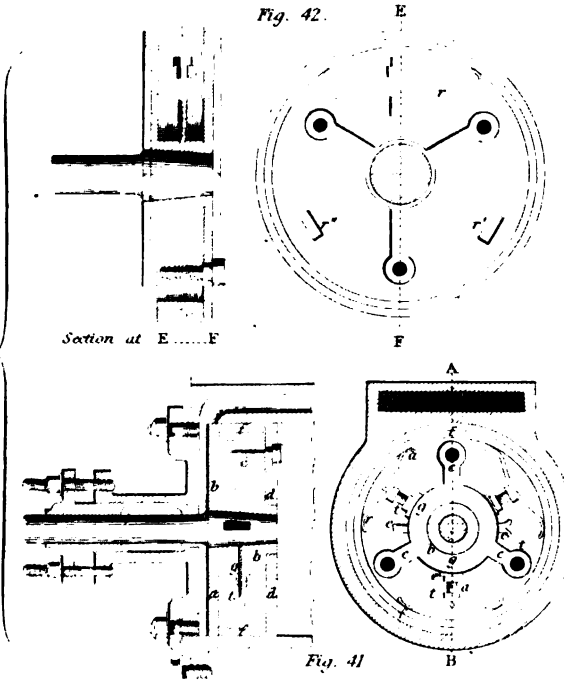
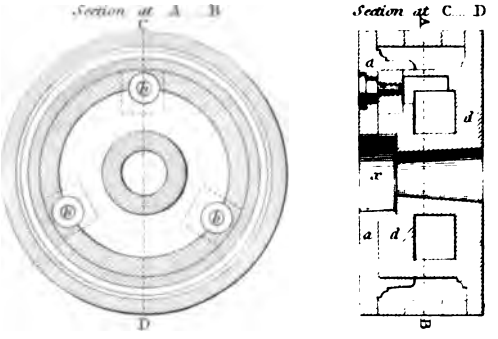


Fig. 41

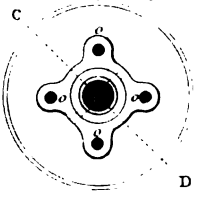
Fig. 44.

Metallic piston packing employed by Jackson.



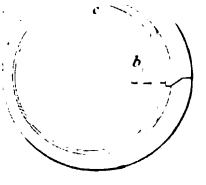
Piston from "Haighe" Foundry.

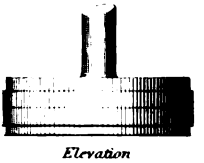
Plan shewing the system of tightening.



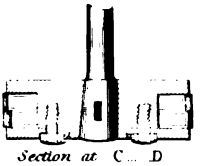
Plan of the under part.

Fig. 45.





Elevation



Section at C... D

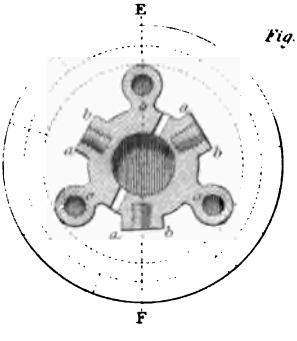
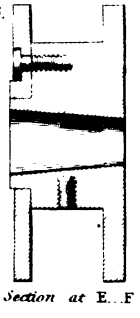


Fig. 46.



Section at E...F

B.R.Davies sculp.

Diagram shewing the whole of the machinery except the eccentrics and the apparatus connected with the distribution of steam

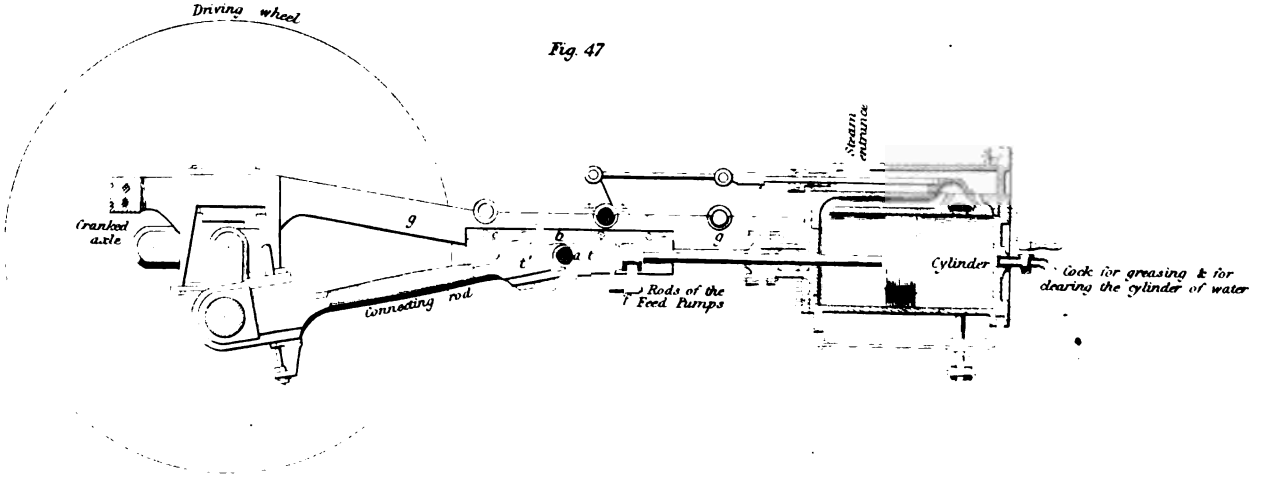
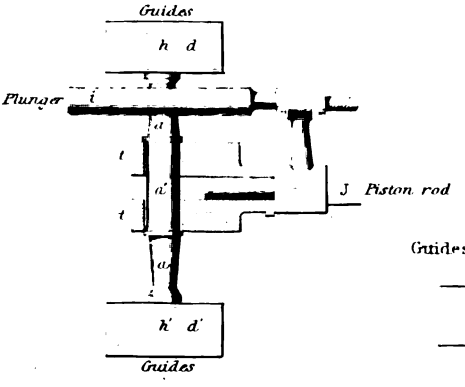


Fig. 47

Plate 27.

Fig. 48.
Plunger of the Pump & Piston rod.



Guides of the Piston rod.

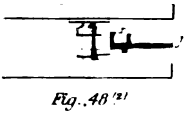
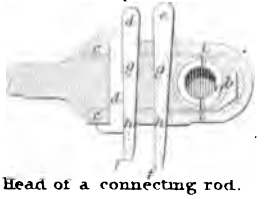


Fig. 49.



Head of a connecting rod.

Fig. 51.
Grease Box.

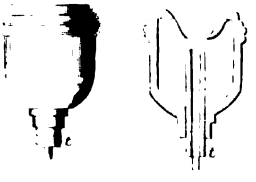


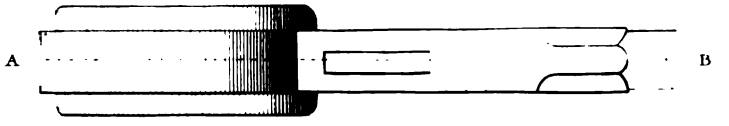
Fig. 50.

Another head of a connecting rod.

Mau

Fig. 52.
Stephenson's Connecting rod.

Plan of head



Section in the middle at A B

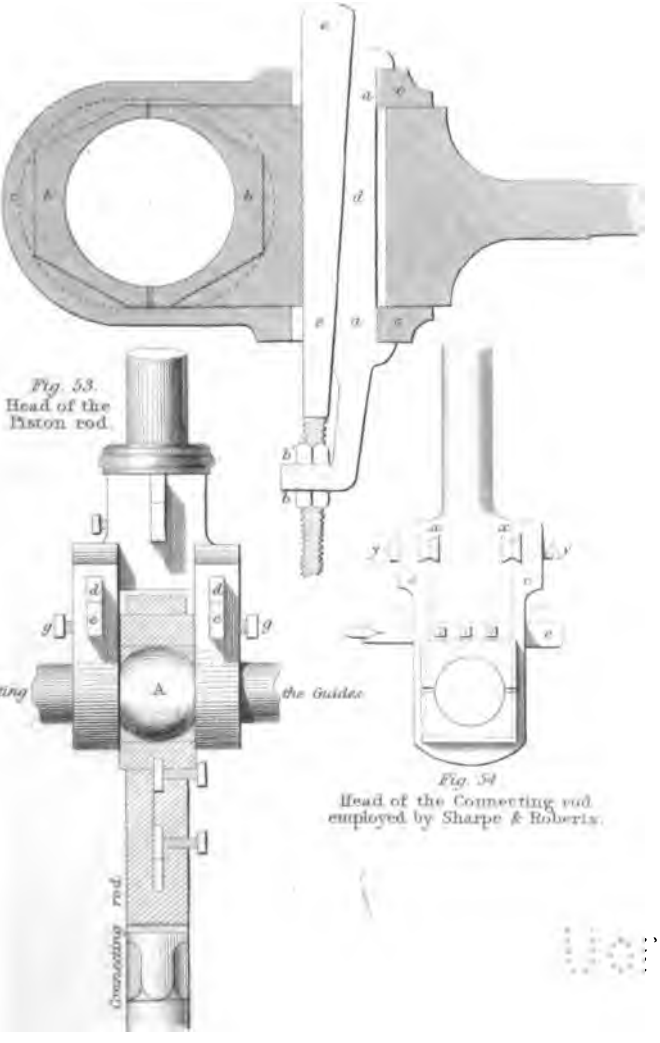


Fig. 53.
Head of the Piston rod.

Fig. 54
Head of the Connecting rod employed by Sharpe & Roberts.

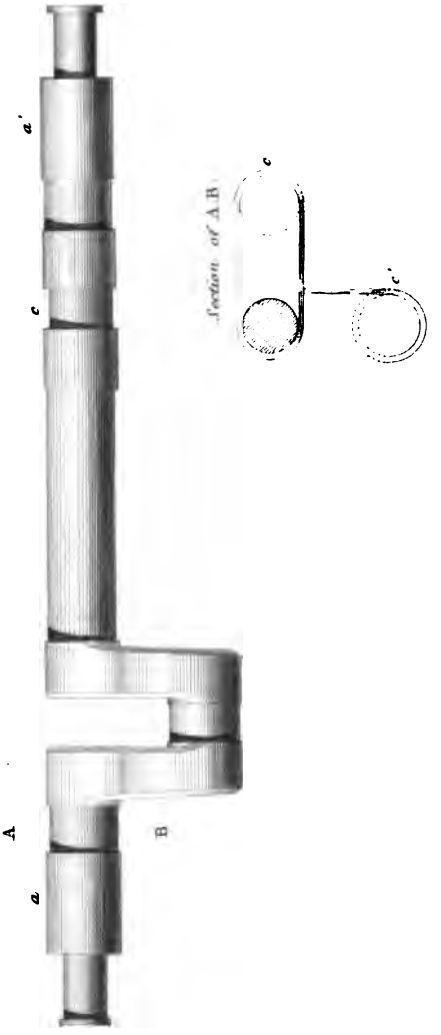


Fig. 55.

Cranked Axle.

R.R.Davies sculp.

Fig. 56.
Eccentric used by Stephenson.

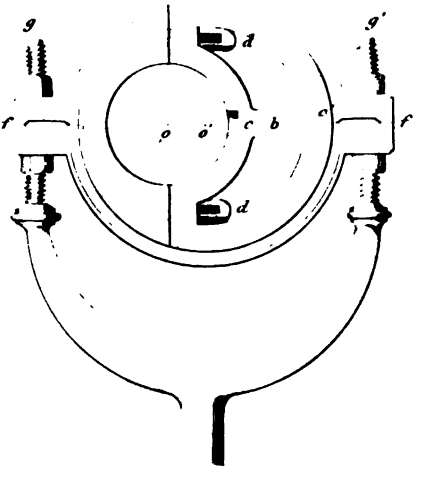
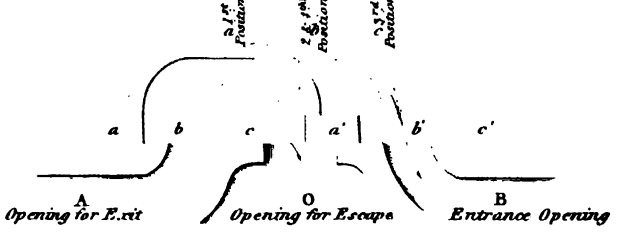


Fig. 57.
Section of the four positions of Slide.

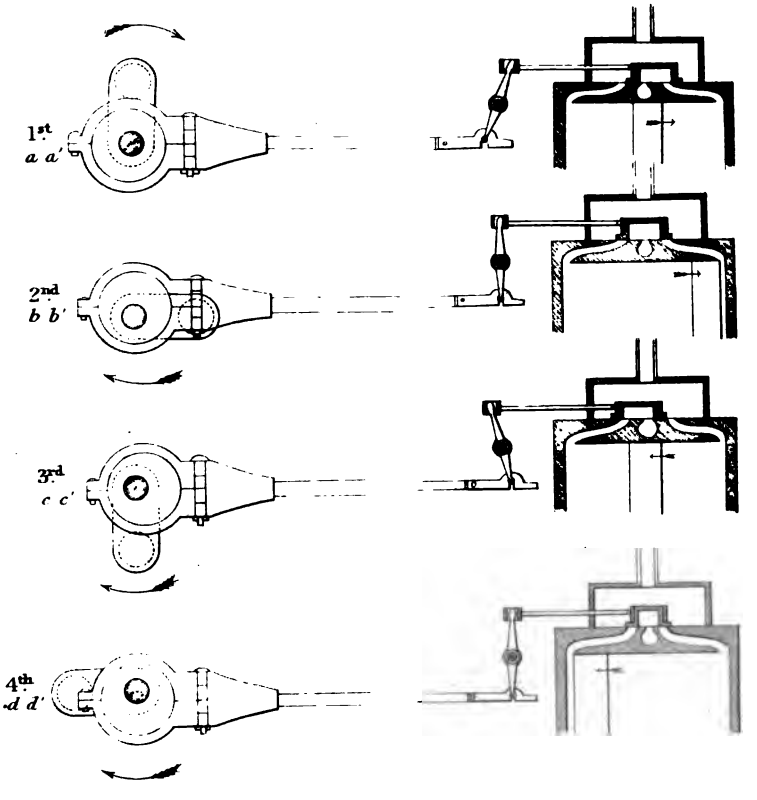


B. R. Davies, sculp.

Plate 32.

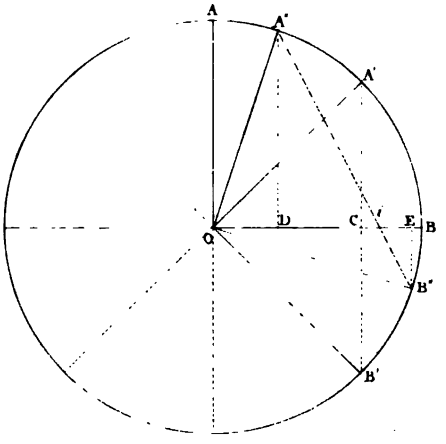
Section of 4 Positions of the Slide Rod & Eccentric for a turn of the wheel forward.

Fig. 58.



B.R.Davies fculp.

Fig. 61.

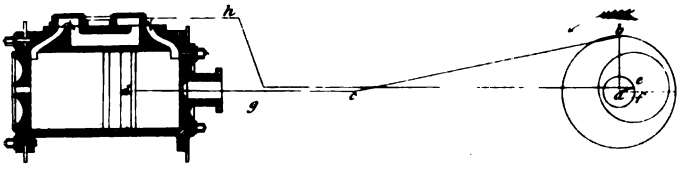


B.R.Davies fc.

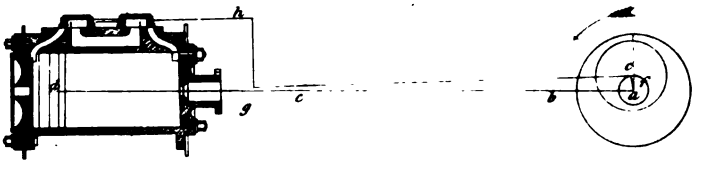
Microfilm

Fig. 62.

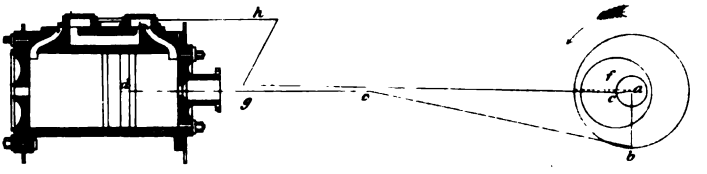
1st. Position



2nd. Position



3rd. Position



4th. Position

B. R. Davies, sculp.

Fig. 63.

Jackson's system of two loose eccentrics.

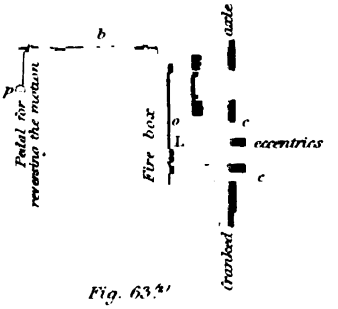
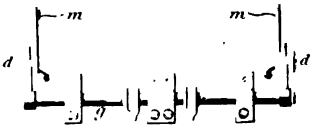
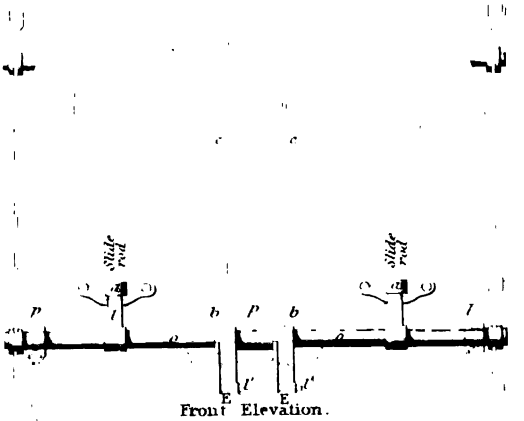
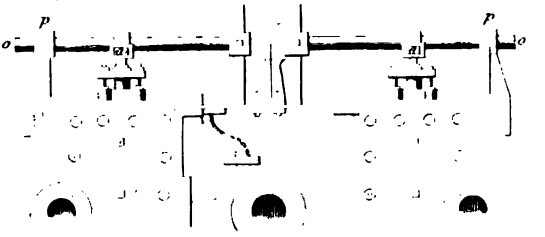


Fig. 63A.





Front Elevation.



Plan

A.R. Jarvis sculp.

BIBLIOTECA

Fig. 64.
Details of the Levers.

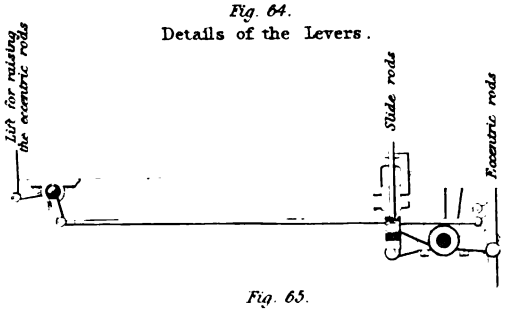
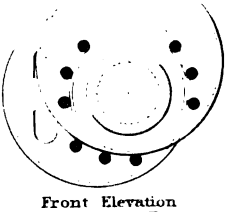


Fig. 65.
Details of two loose eccentrics.


Front Elevation shewing the collars.

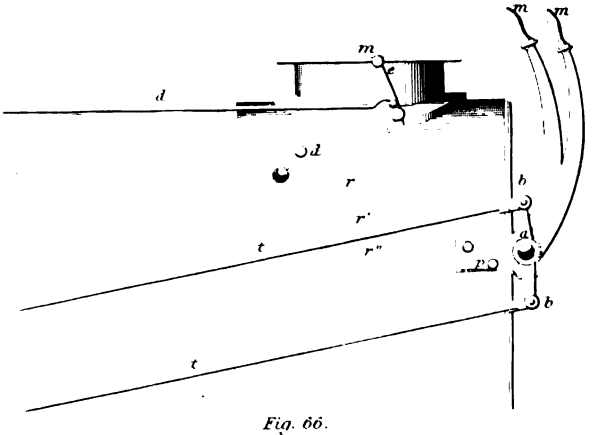
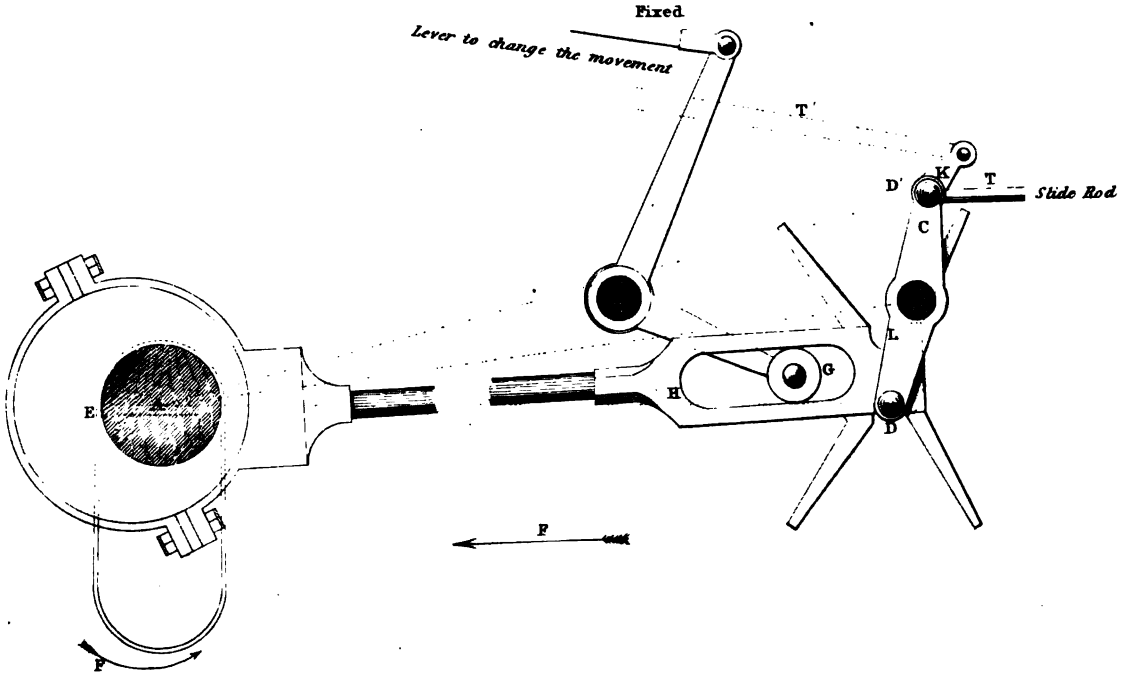


Fig. 66.
Levers and hand gear.

Fig. 67

Mode of arrangement with two eccentrics.



B.H.Davies Jr.

Plate 39.

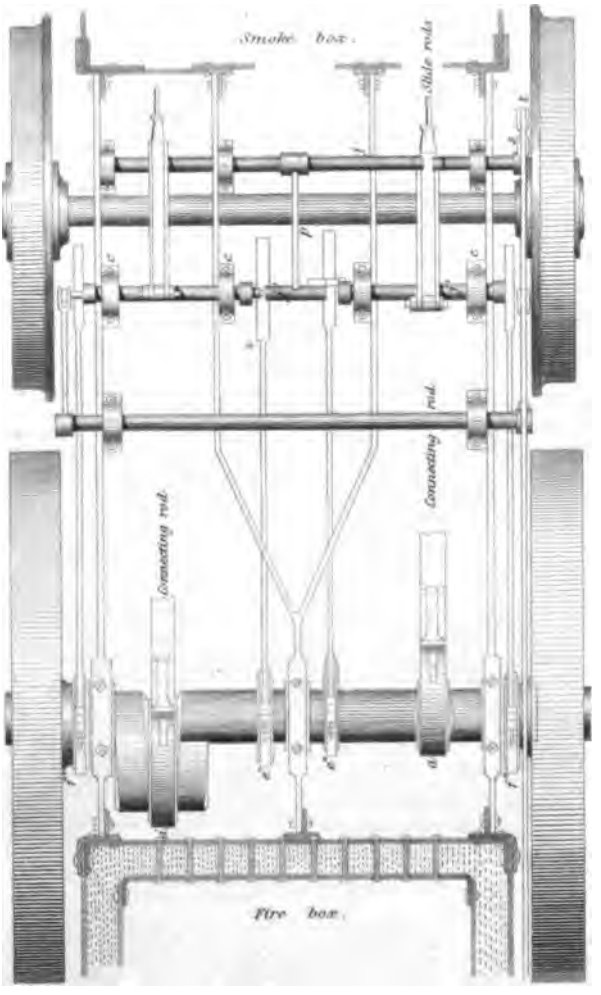


Fig. 68.
Diagram shewing the mode of arrangement adopted in Stephenson's six wheeled engine

R.R.Davies sc.

Fig. 69.

Diagram shewing Stephenson's system of Levers, Eccentrics, Slides & Pistons & their position at the termination of the fore stroke.

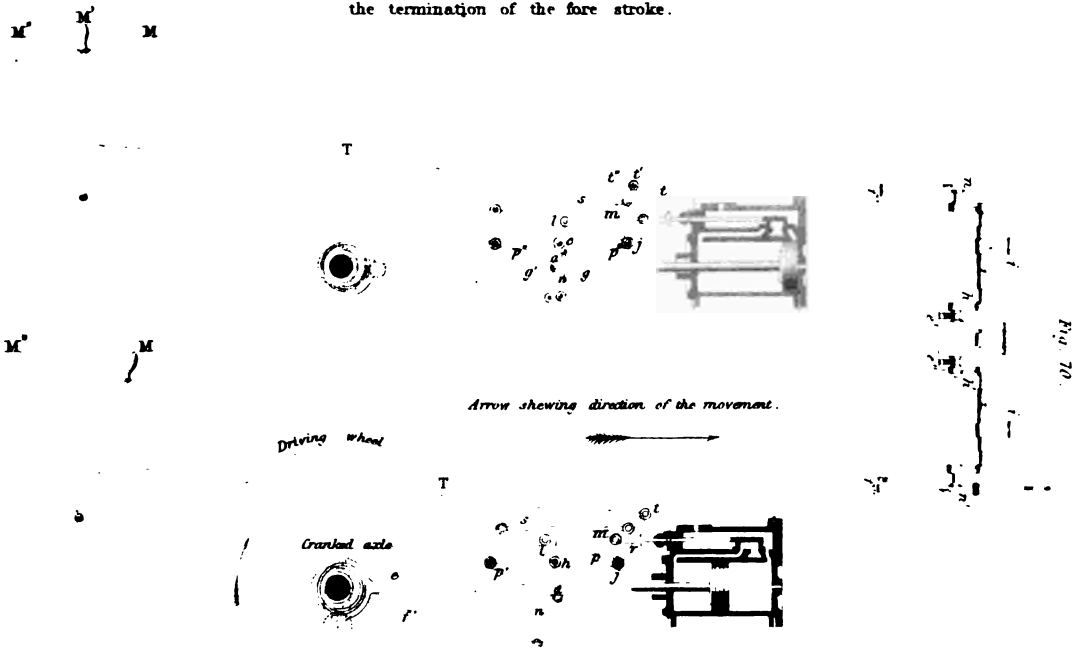


Fig. 69 bis

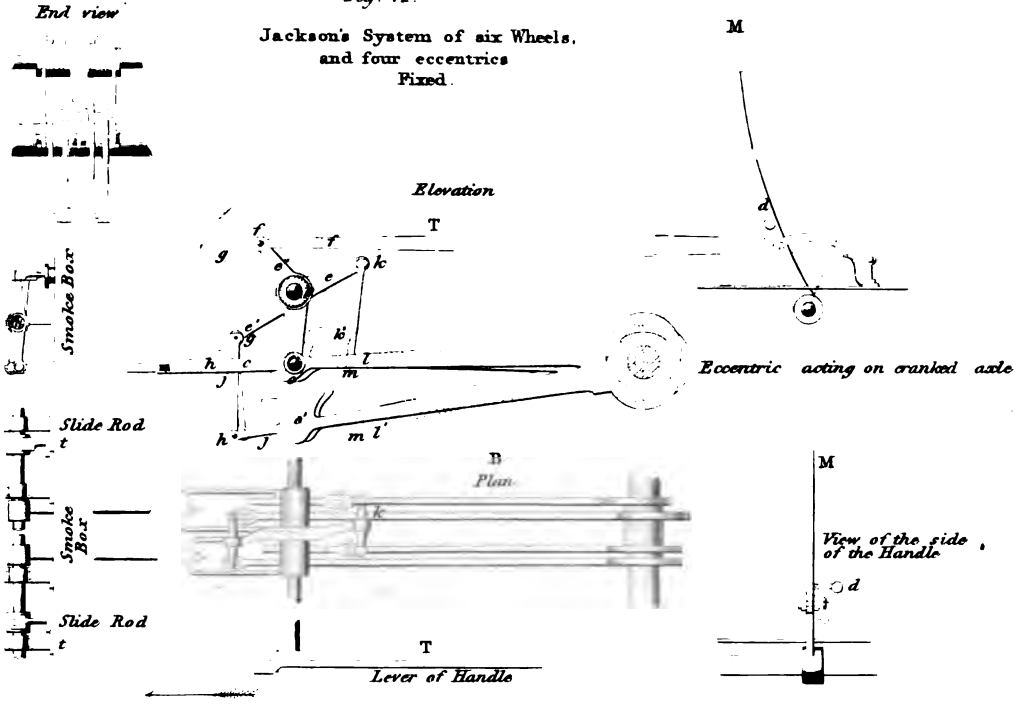
Fig. 70.

R.R.Davies fc.

Plate 41.

Fig. 71.

Jackson's System of six Wheels, and four eccentrics Fixed.

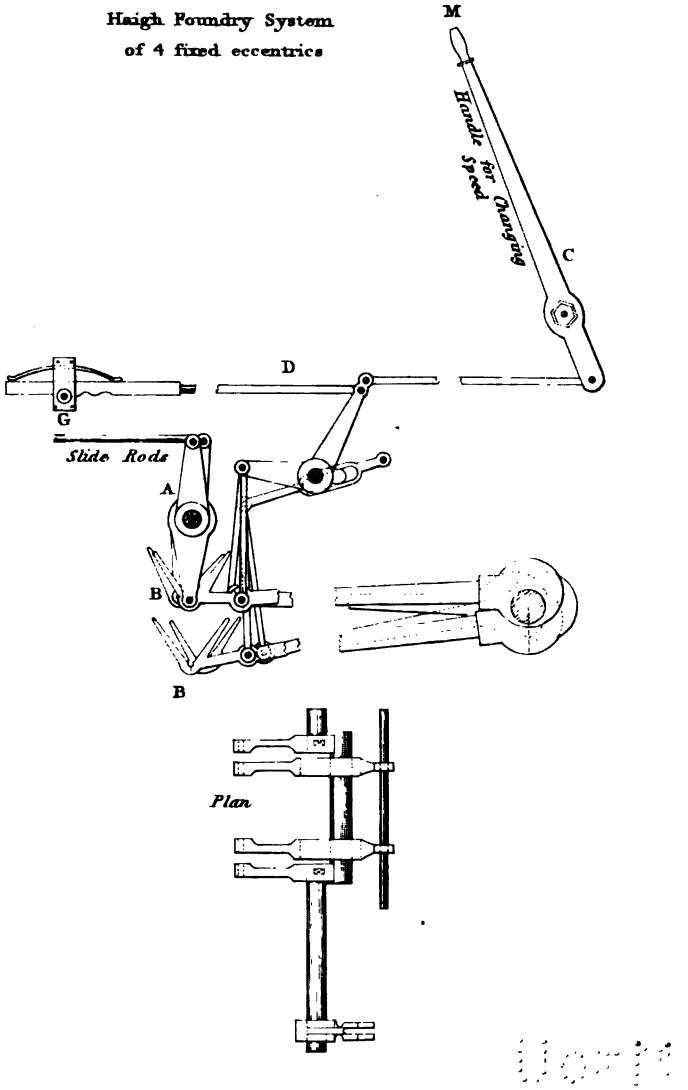


R.R.Davies fc.

Plate 42.

Fig. 72

Haigh Foundry System of 4 fixed eccentrics



B. R. Davies, sculp.

Fig 73.

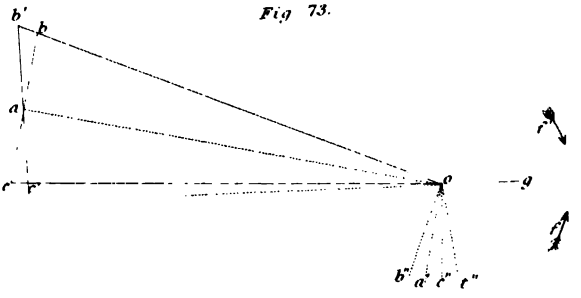
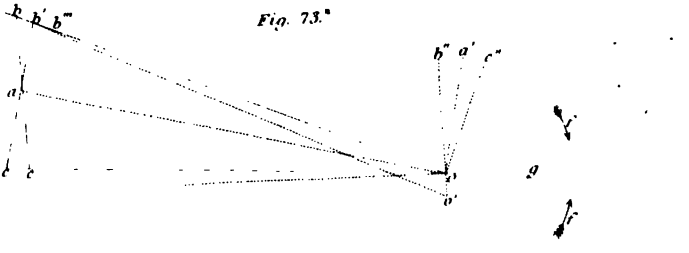


Fig. 73.*



B. R. Davies, sculp.

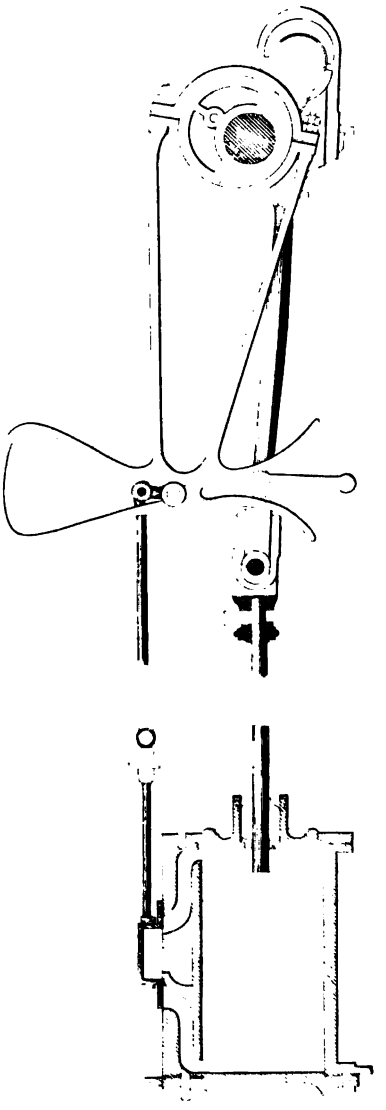


Fig. 74.
System of two fixed eccentrics of Mr Cave.

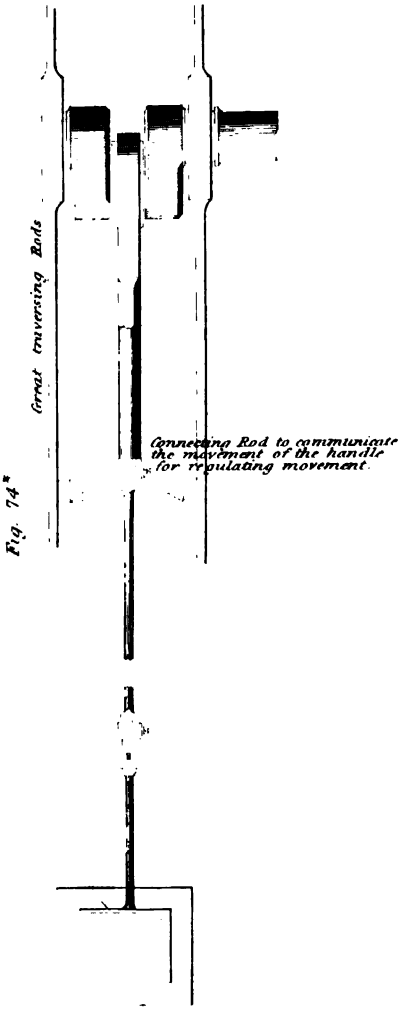


Fig. 74*

B.R.Davies fc.

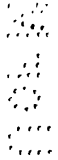
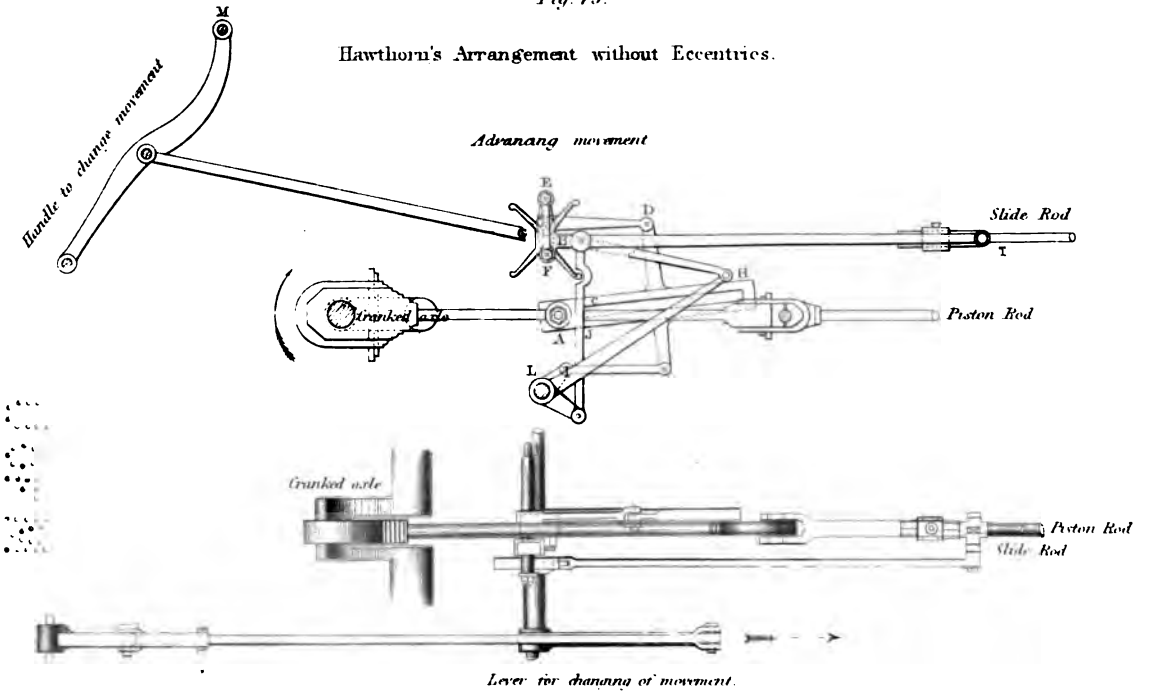


Fig. 75.

Hawthorn's Arrangement without Eccentrics.



R.R.Davies jr.

Plate 46

Mrdu

Fig. 77.

Boiler supporters on outside Frame.

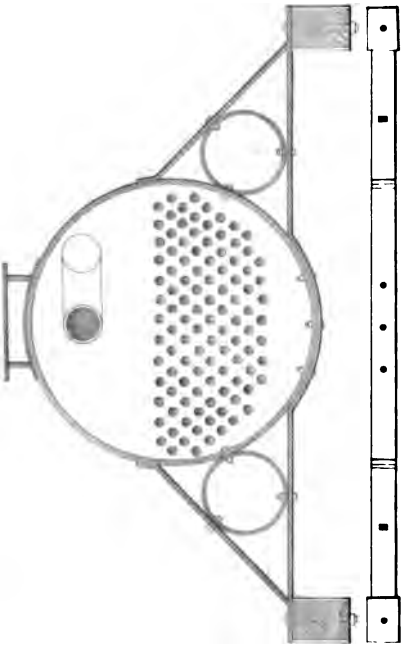
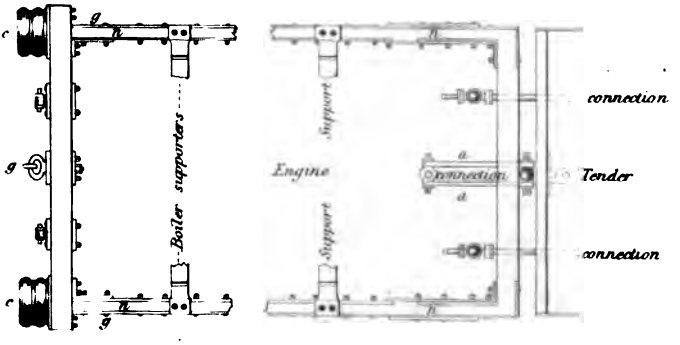


Fig 76.

Plan of outside Frame



B.R.Davies fc.

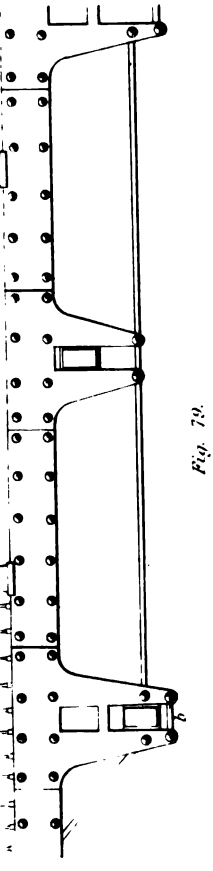


Fig. 78.
Frame outside the wheels.

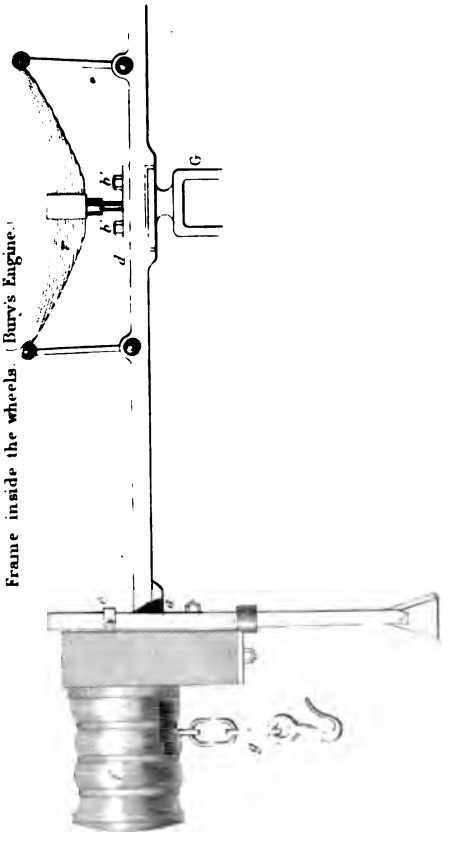
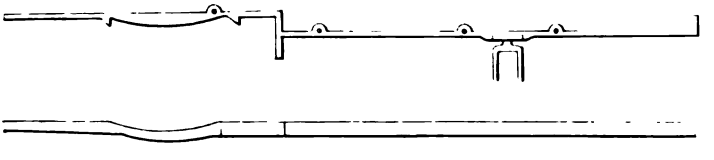


Fig. 79.
Frame inside the wheels. (Bury's Engine.)

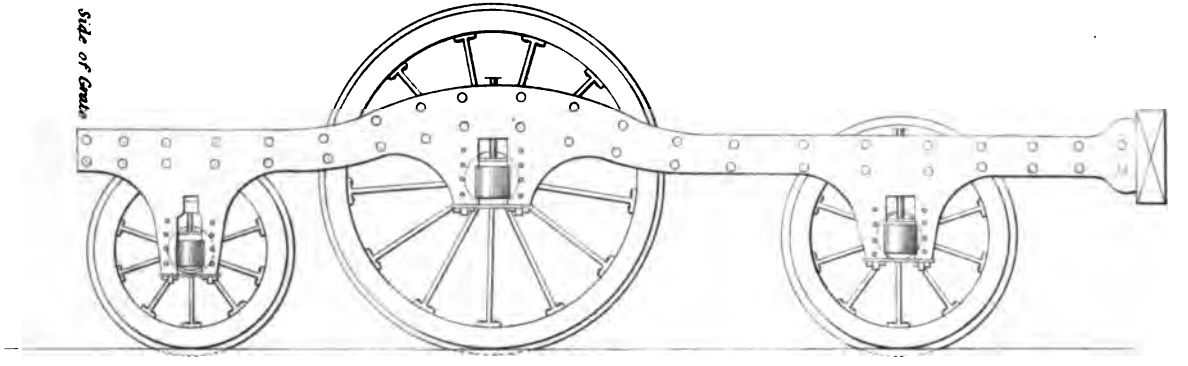
Bury's Frame.



B.R.Davies Sc.

Fig. 79.[9]

Sharp & Roberts's outside Frame.



B.R.Davies fc.

Plate 19

Fig. 80.

Tayleurs large cross Pieces

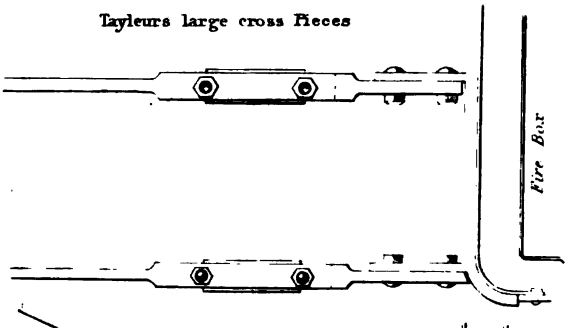


*Fig. 80.**

Stephenson's arrangement.

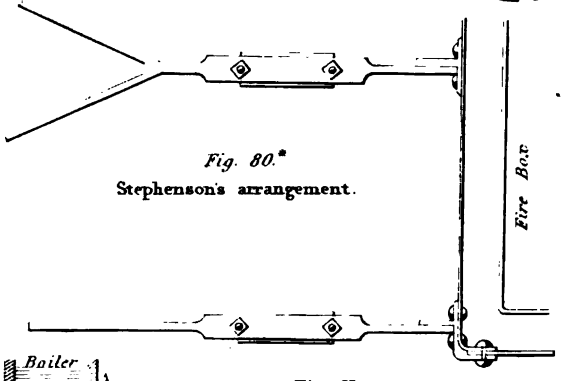


Fig. 81.

Cross Pieces used in the New Jackson.

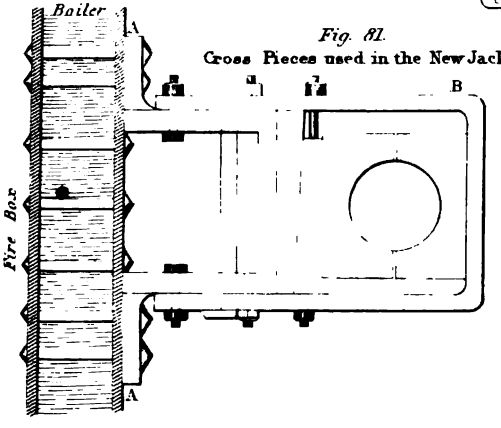


Fig. 82.
Tallow Box and Guide.

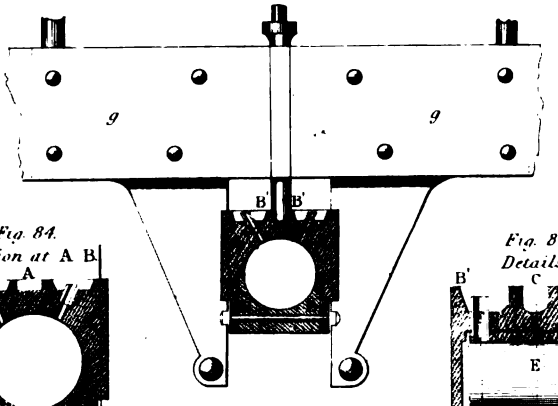


Fig. 84.
Section at A B.

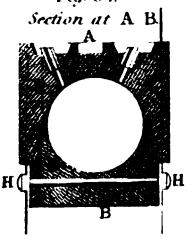


Fig. 83.
Details.

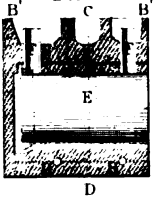
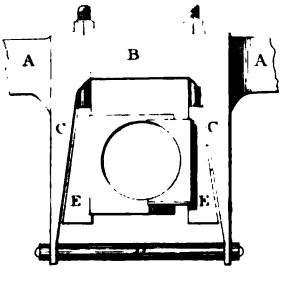


Fig. 84.(2)

Fig. 83.(2)
Section at C D.

Fig. 83.
Tallow Box of principal crofs Pieces



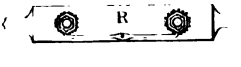


Fig. 89.[a]

Concufsion Spring of Tender

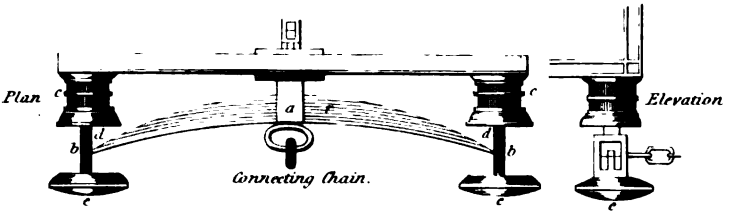


Fig. 89.

Suspension spring of the Tender.

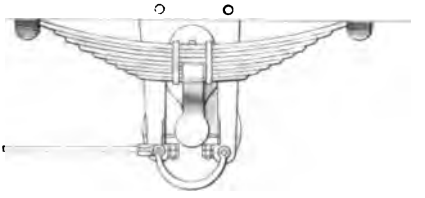
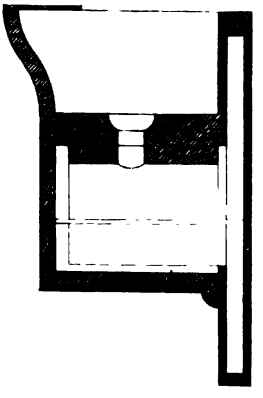


Fig. 87.

Section at A B.



Tender Tallow Box.

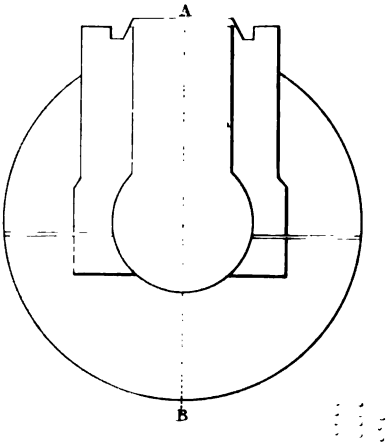


Fig. 86.
Tallow Box of large croſs Pieces

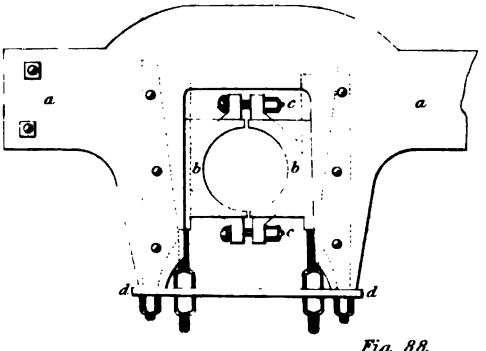


Fig. 87.
Section of a Tallow Box used for the Carriages.

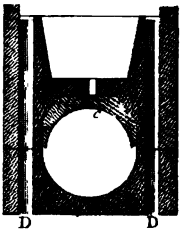
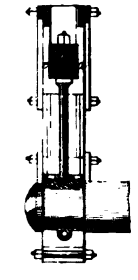


Fig. 88.
Outside Frame, Tallow Box with Guide.

Section at A B.



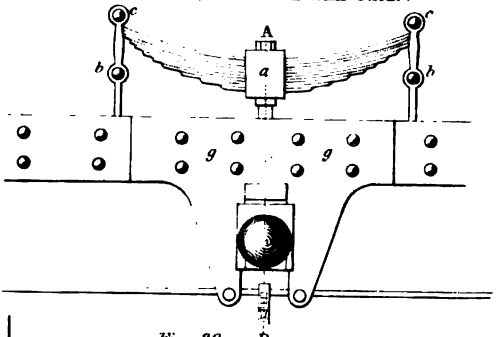


Fig. 89. B
Another Frame with springs underneath.

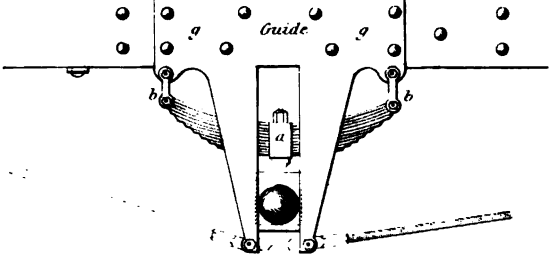


Fig. 90.
Section of driving wheel used by Stephenson.

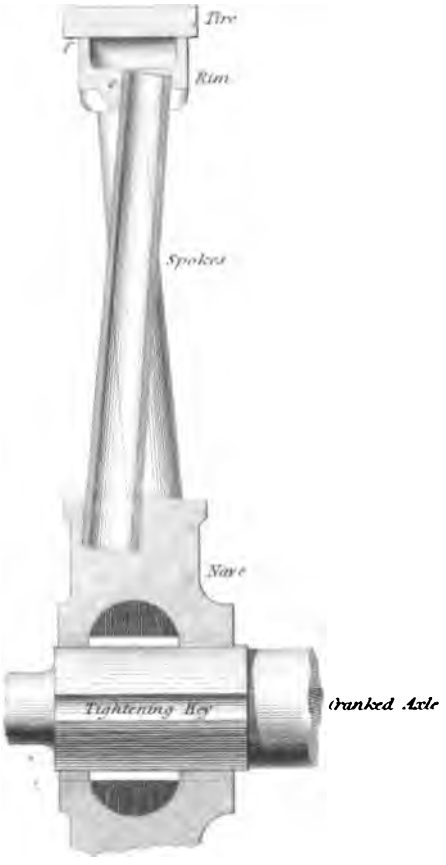
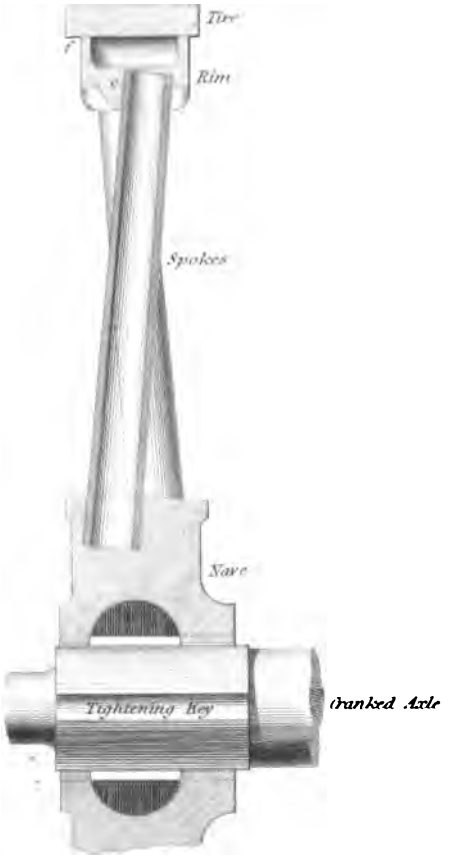
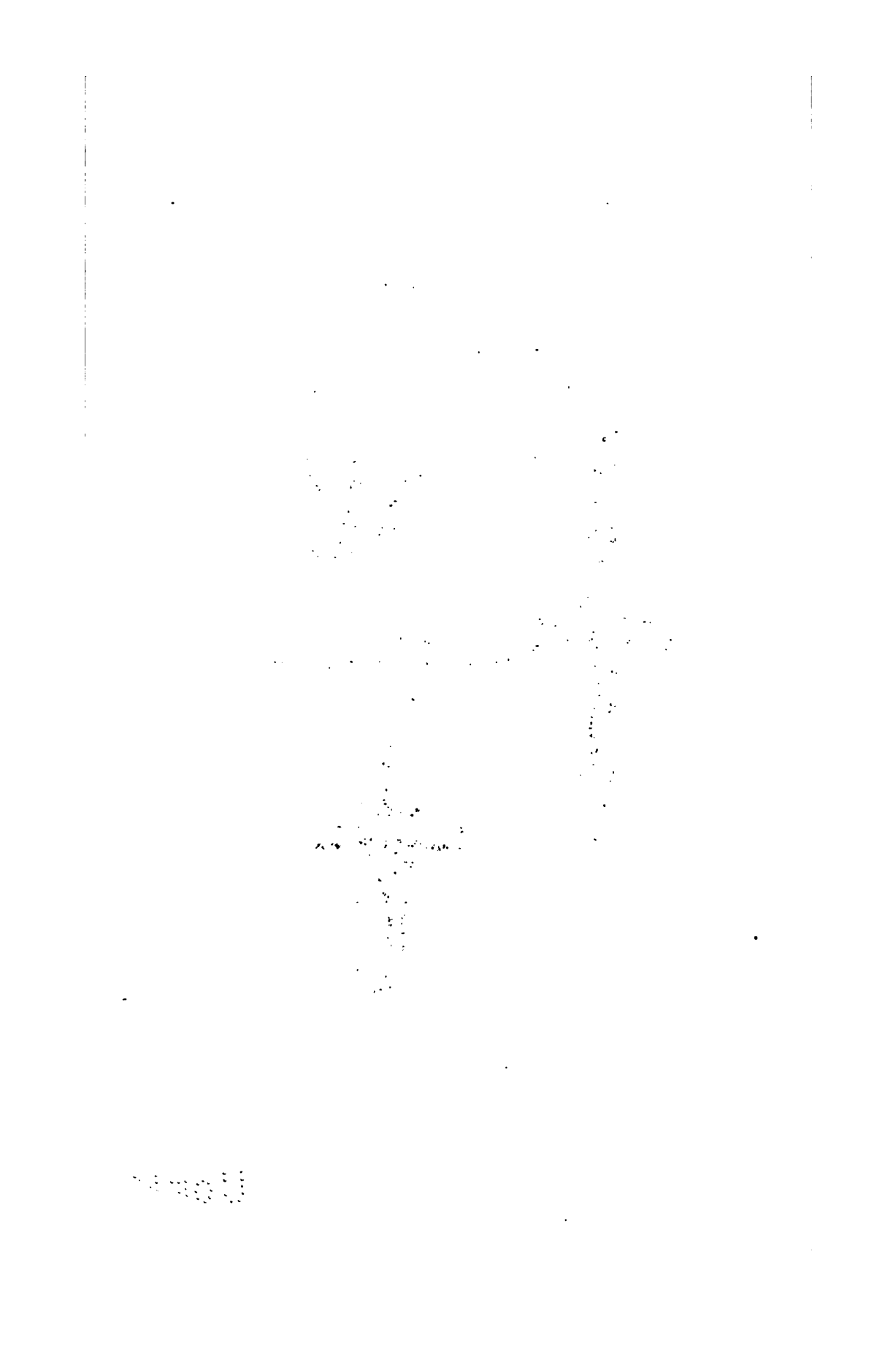


Fig. 90.
Section of driving wheel used by Stephenson.



B. R. Davies, jr.



Style of wheel used by Jackson.

Fig. 92.

Section of Centre *Front View.*

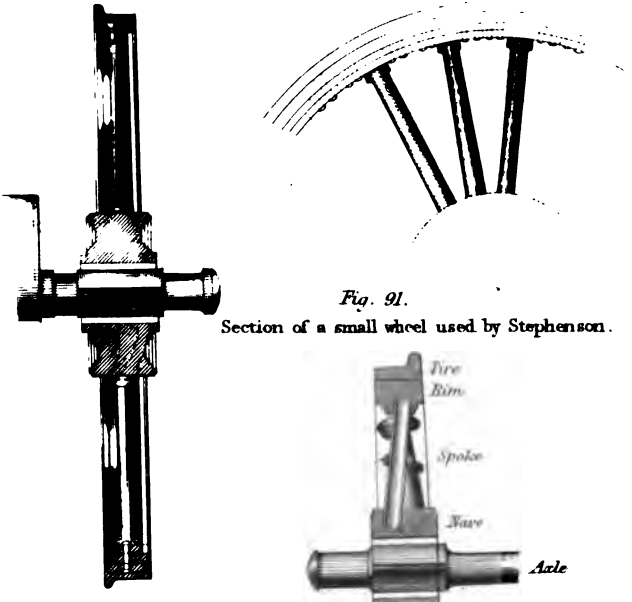


Fig. 91.

Section of a small wheel used by Stephenson.

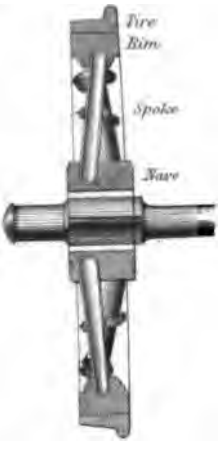
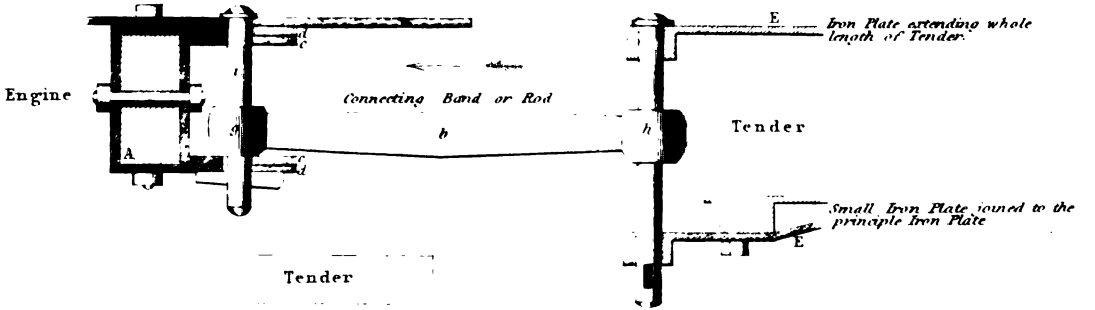


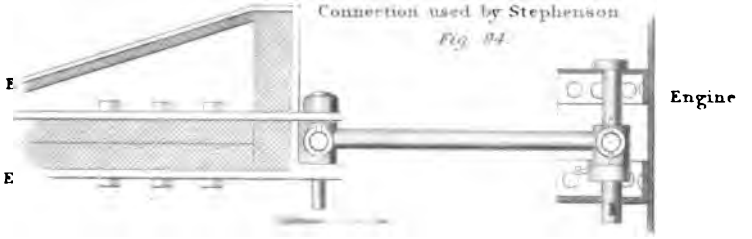
Fig. 93.

Connection of Engine and Tender



Connection used by Stephenson

Fig. 94.



R.H.Davies fc.

Plate 56.

Feed Pumps between the Engine & Tender

Fig. 95.

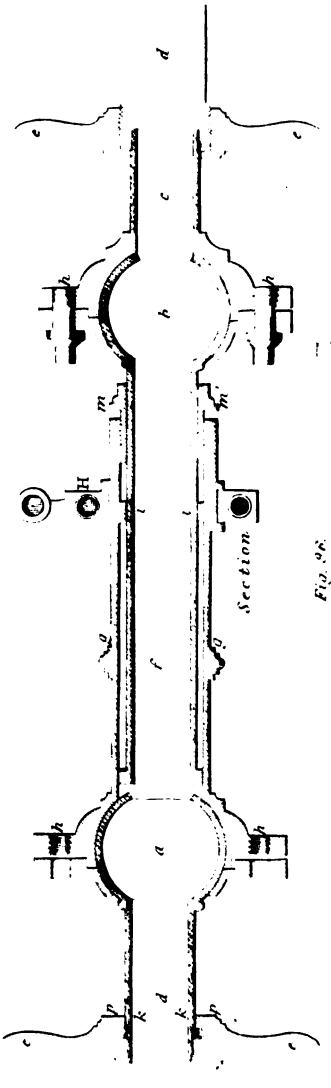


Fig. 96.
Elevation

B.R.Davies sc.

New mode of connection of the Tender with the Boiler.

Fig. 97.

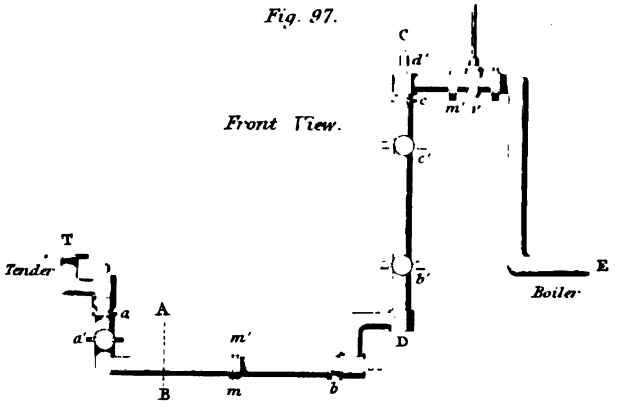
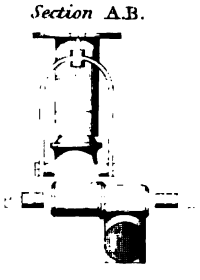


Fig. 98.



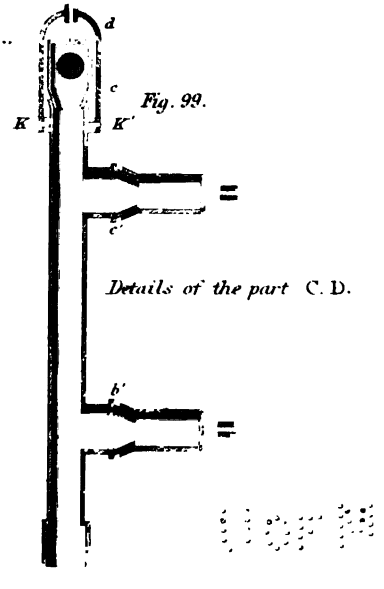


Fig. 99.

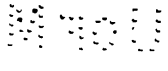


Fig. 100.

Section of Water tank of Tender.

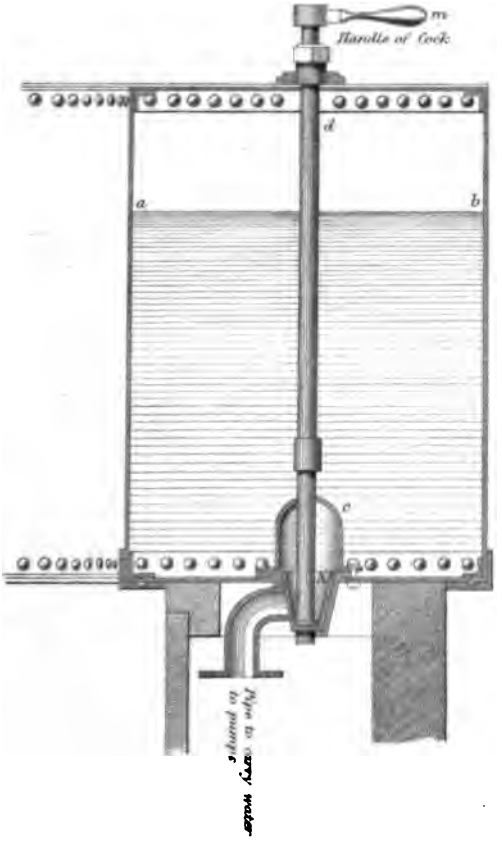
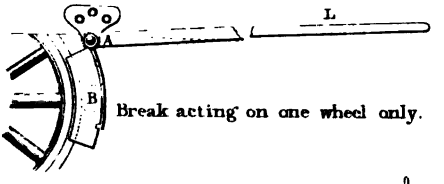


Fig. 101.



Break acting on one wheel only.

Fig. 102.

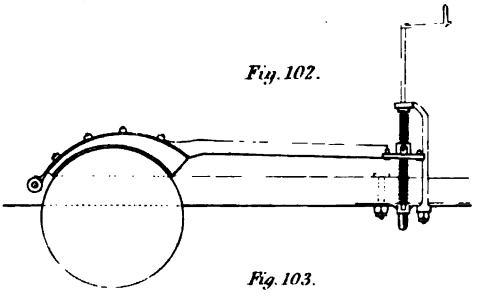
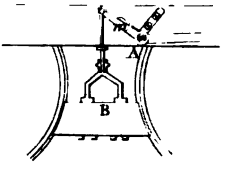


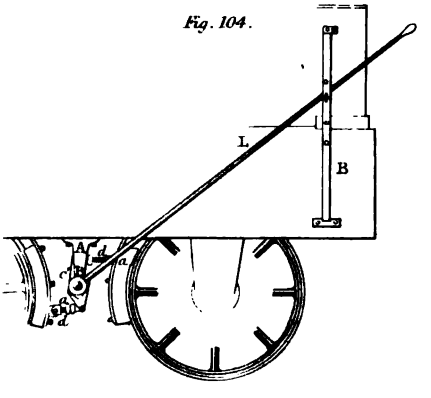
Fig. 103.

Double Break



Break used on the St Germain Railroad.

Fig. 104.



R.R Davies fc.

A double Break.

Fig. 105.

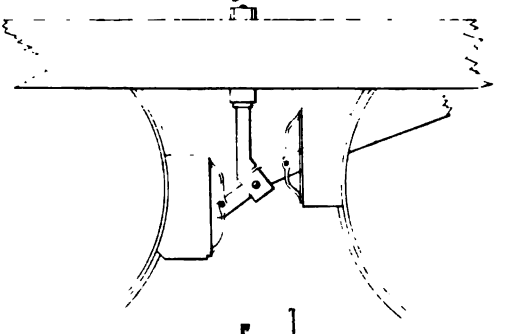


Fig. 106.

Another double Break.

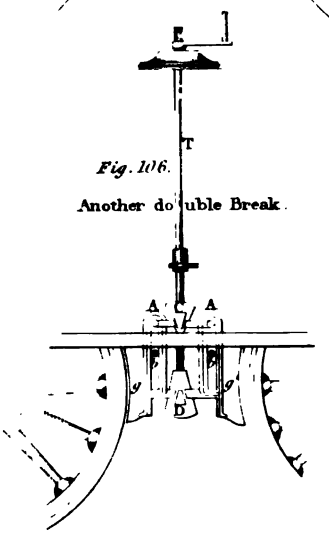
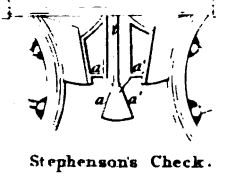


Fig. 107.



Stephenson's Check.

B.R.Davies, sculp.

Fig 108.

Hawthorn's Tender Break.

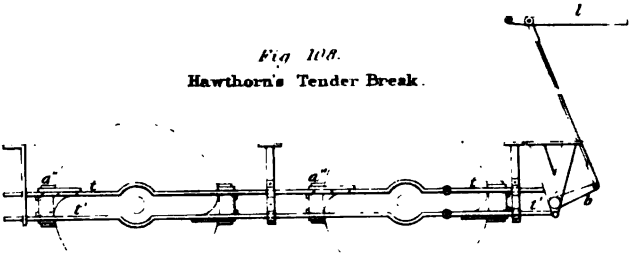


Fig. 109.

Break for Carriages used in England.

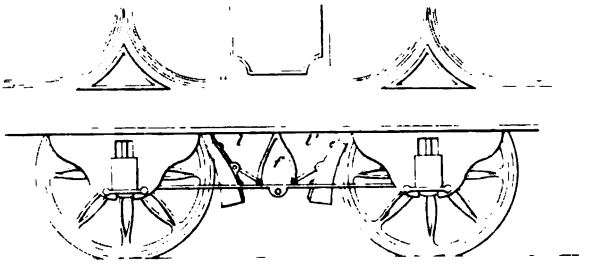
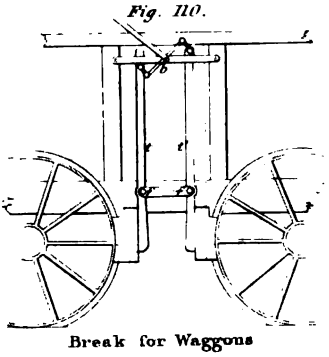


Fig. 110.

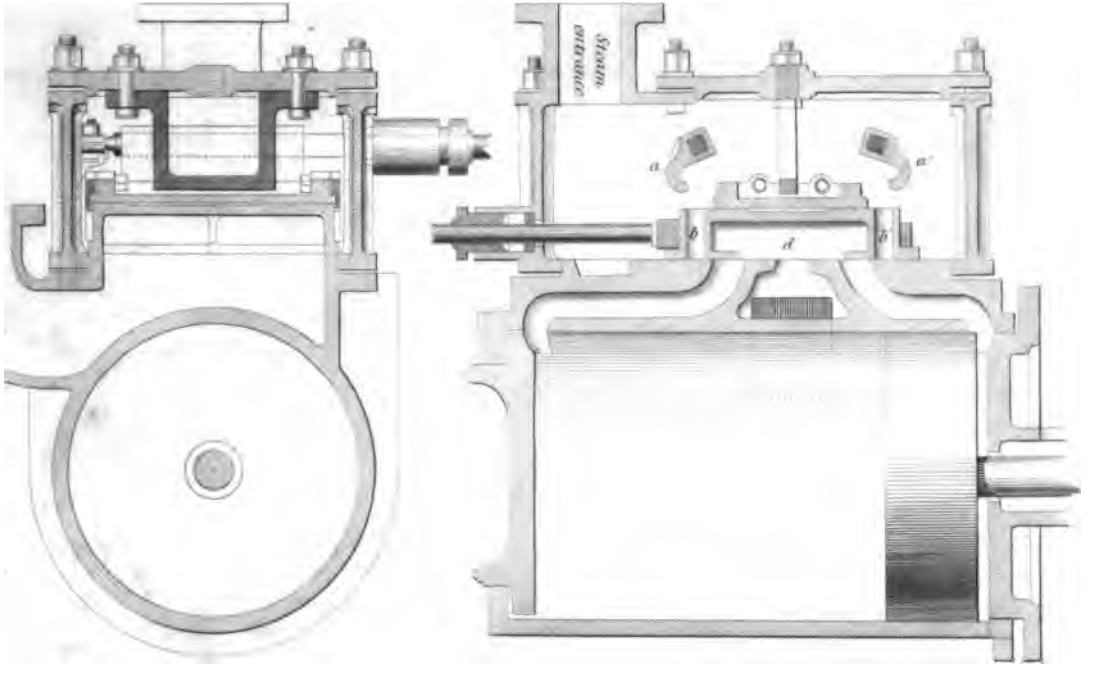


Break for Waggons

B.R.Davies, sculp.

Edwards's Stop applied to Taylor's Engine the St Germain.

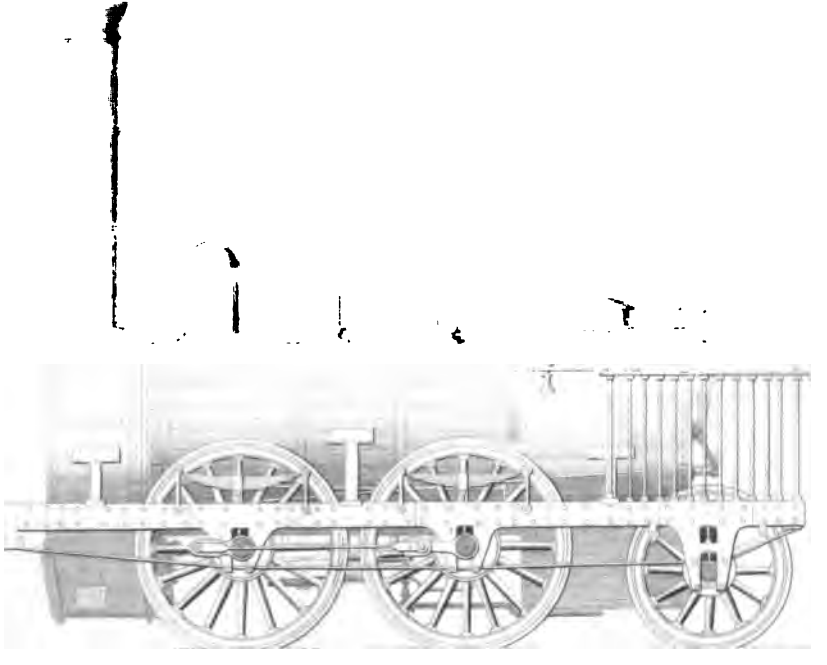
Fig. III.



B.R.Davies fc.

Plate 63

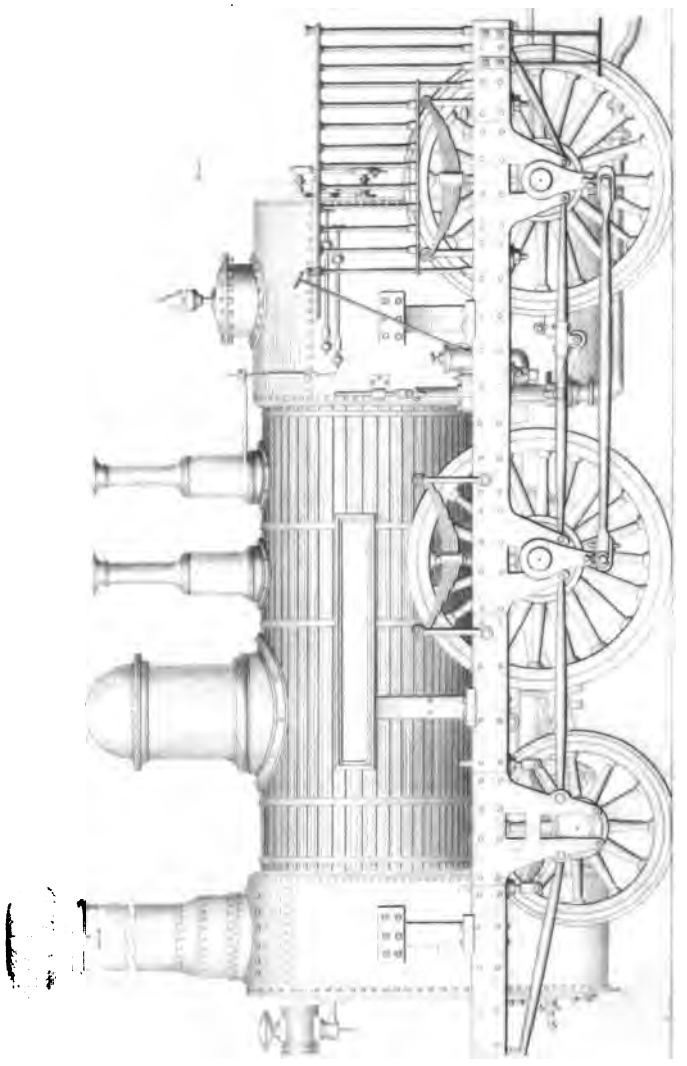
A six wheeled Locomotive Engine for the conveyance of Merchandize.



B.R.Davis jr.

Plate 61.

Stephensons Engine for the conveyance of Merchandize.



B.R.Davies jr.

Stephenson's Patent Locomotive Engine.

with 4 fixed Excentrics.

Plan

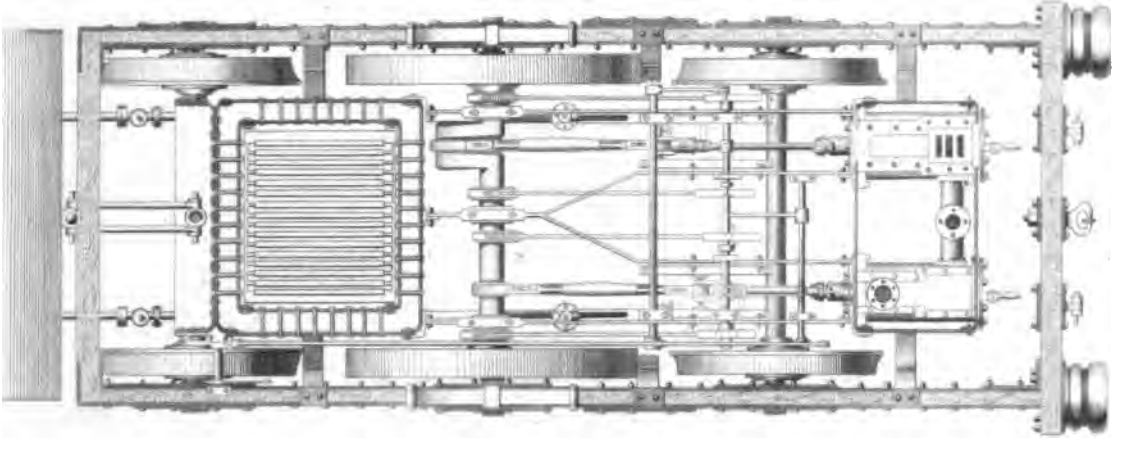
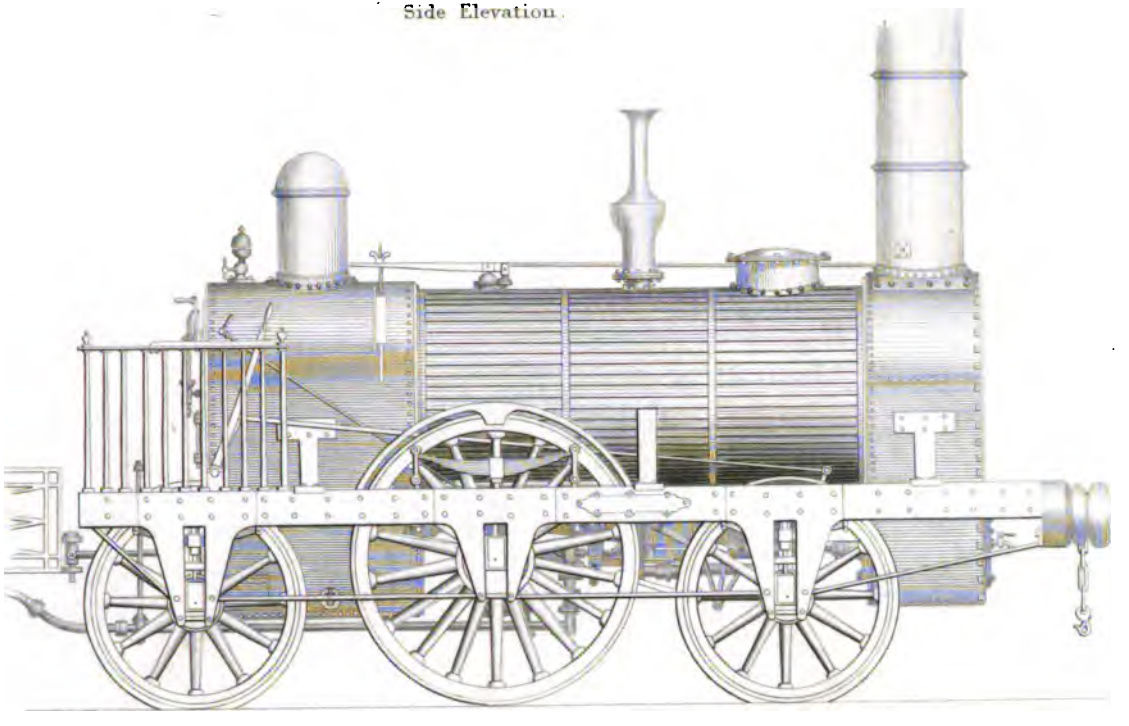


Plate 66.

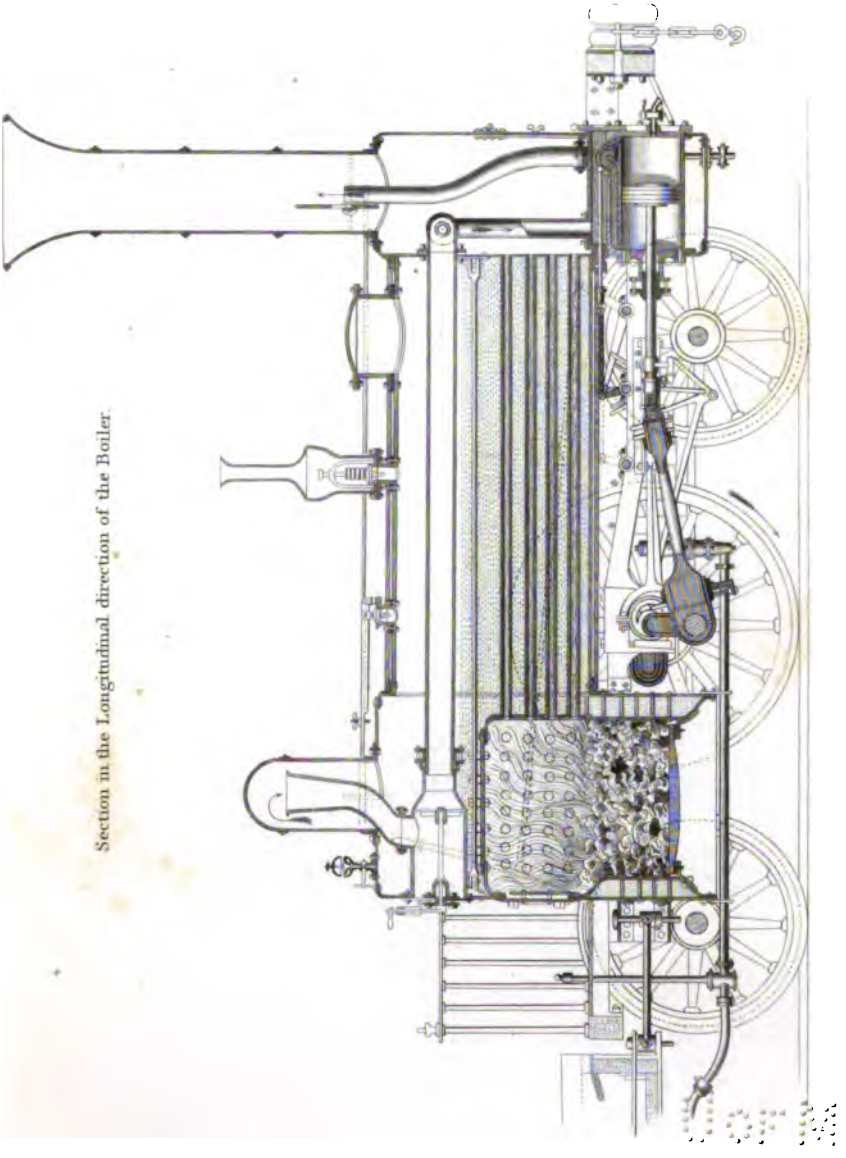
Side Elevation.



E.R.Davies fe.

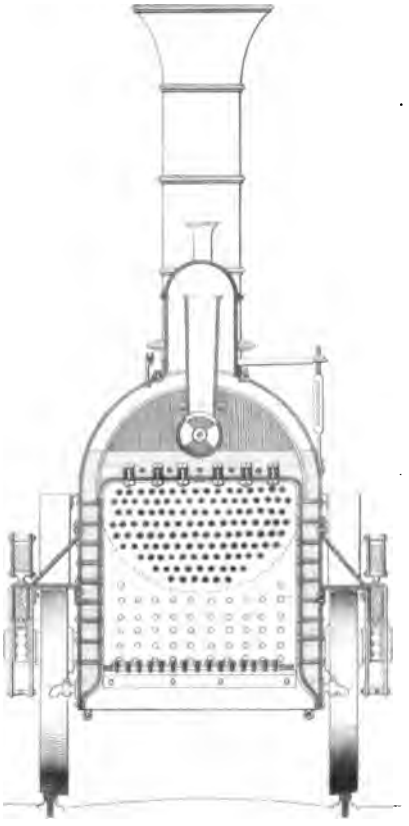
Plate 67.

Blank

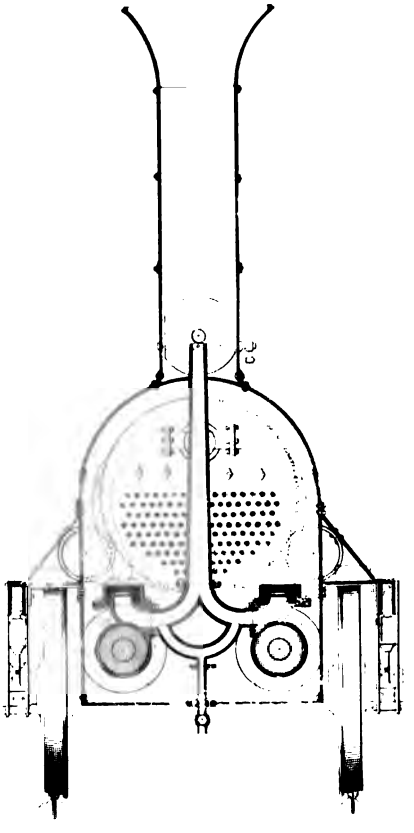


Section in the Longitudinal direction of the Boiler.

Transverse Section through Fire Box.



Transverse Section through Smoke Box.



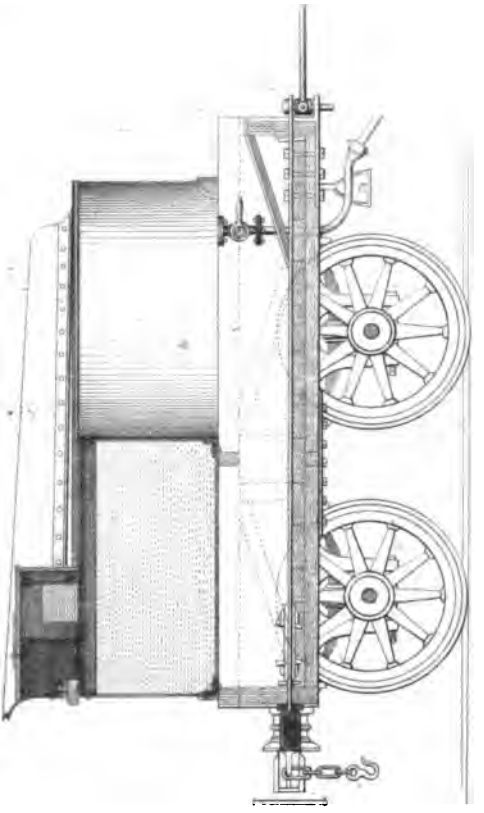
Mod

Plate 71.

Side Elevation of the Tender of Stephenson's Locomotive

B.R.Davies sc.

DRAFT



Longitudinal Section of the Tender.

NOT

engines, as small and light as possible, leave no more room than is absolutely necessary for the movement of each of these pieces. If the distances between the axles were to alter by the lengthening of the connecting-rod, or otherwise, the piston would come in contact with the cover of the cylinder at the termination of its stroke. This constant uniformity in the length of the connecting-rod can only be obtained by adjusting the glands as they wear away by use.

The head of the connecting-rod adopted by Sharp and Roberts is, in our opinion, preferable to those of other engineers, and merits a detailed description, *see* fig. 54 (plate 29).

The stirrup is fastened to the body of the connecting-rod by two dove-tailed joggles, *x x*, which are secured by cross-bolts, *y y*. The adjusting is effected by means of a key, *e*, which is held by three force-screws. It will be perceived, that the engineers have taken every precaution to prevent the stirrup getting unfastened from the connecting-rod; they are joined together so as to form one piece. The stirrup, too, often breaks away from the connecting-rod, when these pieces are merely held together by keys; and unless the engine-driver is very attentive to keep them tight, serious accidents might arise from it, since the piston, being free, would strike against the bottom of the cylinder with all the force transmitted to it from the steam, whereby the piston-coverings and the cylinder might be destroyed. The piston of the Jackson has been thus broken, and the cylinders of the two engines of Tayler have been broken by the fall of the keys, which were immediately followed by the connecting-rod itself. Another advantage of this connecting-rod (fig. 54) consists in the outer surface of the gland being square, by which the wedges, which are necessarily placed behind, hold better as it wears, and the gland cannot turn in the stirrup under any circumstances.

The turning-axle joining the head of the connecting-rod with the cranked axle is spherical, like that at the other end

of the connecting-rod, to facilitate the movements of torsion, which we have before alluded to.

34. *On the Cranked Axle.*—This part is formed of a single piece of wrought-iron; it is about 6 feet 6 inches in length, and from $4\frac{3}{4}$ to about 5 inches in diameter. The cranks *c c'* receive the two connecting-rods, and, therefore, corresponding to each of the pistons; they are about 8 to 9 inches long, and are fixed exactly at right angles with each other. The wheels are keyed on the parts *a a'*, and therefore turn at the same time and in the same direction as the axles. The axle is reduced in diameter, outside the wheels, to about $4\frac{1}{3}$ inches, on a length of about $4\frac{3}{4}$ inches, and is terminated at the end by a collar. These gudgeons turn in brass bearings, on which the engine rests. The cranked axle is turned throughout the whole of its length.

The instant that the piston receives the action of the steam on one side, it transmits the same to the cranked axle by means of its rod and the connecting-rod. If the piston is about 11·81 inches in diameter, the area equal to ·6889 square feet, and the pressure equal to 8732·7 lbs. per square foot, then the total amount of pressure upon the piston will be 6019 lbs. Now, as the cylinders and cranked axle are constantly maintained at the same distance, the alternating movement is wholly employed in turning the axle and wheels, which produces the locomotion. The cranks being set at right angles with each other, enables the axle to pass the dead points; that is to say, at the moment one of the cranks is horizontal, and in a line with the axis of one of the pistons and cylinders, the other is vertical, and consequently perpendicular to the rod of the other piston, which is the best position to receive the movement.

The different positions which the connecting rods require to take, promotes friction on the guides of the piston, when they are oblique; the friction is nearly insensible when they are horizontal, since it is produced by the weight of the connecting-rod only. The connecting-rods, therefore, require to

be made as long as possible to diminish the friction, since the longer they are, the smaller is the angle which they make with the horizon, and the less the friction.

35. *On the Motion of the Engine.* — The motion of the engine, resulting from the action of the steam upon the cranked axle, would not take place unless the wheels adhered to the rails; this adhesion is in proportion to the weight of the engine, and is a certain fraction of it. If the weight to be propelled exceeds this fraction, the adherence is insufficient, and the locomotion does not proceed. The wheels turn on the rails without changing their position; this, however, seldom happens in practice, the adherence being nearly always sufficient. It only occurs at the time of starting, as it then has to overcome the vis inertia of the train. This inconvenience is remedied by diminishing the opening of the regulator, by which the pressure on the piston is reduced. The following method is sometimes employed to put the train in motion, when the power of the engine is not expected to be sufficient. The whole of the waggons are pushed one upon the other, so that the chains are no longer stretched out, but hang down loosely, when the engine has to overcome the inertia of the waggons singly, one after the other, so that it obtains a start before the total weight operates upon it. The adherence of the wheels is not always the same; it is greater when the wheels are very clean, perfectly dry, or quite wet; and it is reduced when the rails are dirty and slightly wet.

It is found that the adhesion of the wheels to the rails is about a seventh part of the weight which they support, when the rails are in good order; and it varies in practice, according to Stephenson, from this limit to a tenth or twelfth, or even a fifteenth in some cases. The great weight on the driving-wheels is accounted for by the form of the engines; it is also necessary to produce an adherence corresponding to the maximum pressure of the steam. Thus, all engines working with four effective atmospheres require to possess adhesion varying from 1-6th to 1-7th, so that the wheels may not slip.

When locomotives were originally introduced, it was thought that the adhesion of the wheels would not be sufficient to move them, and several means were employed to change the rotative movement to a continuous rectilineal course. These consisted at first of levers, which moved like two legs behind the engine. Cogwheels were afterwards adopted, fixed on the driving-axle, and moving on an endless chain, or on rack work. The two wheels of merchandize-engines are coupled by a connecting rod, furnished with brass bearings, in such a manner that two axles receive the movement of the pistons when the adhesion is more considerable, since it is loaded with their weight. The four driving-wheels support in this case nearly the whole weight of the engine, while the two driving-wheels of passenger-engines support rather less than one half that of the engine. It is necessary, if the wheels are coupled, for the cylinder to incline, that the piston-rod may pass under the axle in front; it is also held necessary that the wheels be exactly of the same diameter, otherwise the road traversed at each revolution of the wheel by one would not equal the length passed over by the other, when it would consequently slide on the rails. This uniformity in the diameters is difficult to be maintained correctly, as the friction wears the two wheels unequally, from the inequality of the hardness of the iron of which they are made; the connecting-rods are further subject to very violent shocks, and often break from the effects of wear, or by the tightness of the bearings. The rupture of the connecting-rod sometimes occasions the engine to run off the rails, and turn on the road. Other ways have therefore been sought of augmenting the adhesion; a roller has been placed between the two driving-wheels, and held tangential to each of them by the aid of a piston moving in a cylinder, which receives the pressure of the steam of the boiler; the friction exercised by this roller on the two wheels binds them together, so that the motion is exerted equally on both pairs of wheels, and the adhesion is rendered proportionate to the total weight of the

engine, instead of being dependent upon one-half, as it is when two wheels alone are driving.

The principal difference existing between passenger-engines and those for merchandize, consists in the greater amount of adhesion given to the latter, so that the weight of the load can be increased without the wheels slipping on the rails.

Some manufacturers have endeavoured to supersede the use of cranked axles, on account of the great expense it is necessary to incur in their manufacture. The cylinders are sometimes placed outside the smoke-box and on the frame, but the condensation of the steam in this case is very considerable, and the power of the engine is diminished. This mode of arrangement is only applicable for very short distances. It has been adopted on the Greenwich railway* to economise the space below the engine, and to admit of the fuel and water being placed there. It therefore appears that the original plan, which is that generally adopted by engineers, should be continued.

36. *On Slides and their Movements.*—We have shown that the alternating movement of the piston is caused by the distribution of the steam on each side of the piston, which distribution is produced by the alternating movement given to the slide. This movement is effected by means of an apparatus called the eccentric, which is placed on the axle of the driving-wheels, and participates in its rotative movement. This apparatus (*see* fig. 56, plate 31) has not the same centre as the cranked axle, the centre of which is at *o*, and the centre of the eccentric is marked *o'*, the distance *o*—*o'* being called its eccentricity. The circular portions, *b* and *c c*, are formed of cast iron, and fixed together, by means of two bolts, with cotton, *d d*. This circle is enclosed in a frame consisting of two copper semicircles *f f'*, which are bolted and joined together by two lugs, and form a collar. The heads of these bolts

* The whole of the engines on the railway from Dublin to Kingstown are furnished with cylinders placed outside the frames; but this line is only about five miles long.

g g' receive the terminations of the slide-rod, which communicates with a lever, conducting the slides. The circular movement of the cranked-axle, therefore, causes the larger radius of the eccentric to pass twice, following the axis of the rod, and consequently allows the slides to take the extreme position twice, which changes the rotatory movement into a rectilinear one. The four extreme positions of the slide are given in fig. 57 and 58, (plate 31 and 32.) The position shown at *a a'* occurs at the moment when the larger radius of the eccentric is horizontal, in advance of the axle of the crank, when the movement is transmitted directly—but it would be behind it if transmitted by means of an intermediate axle at a fixed point, as shown in fig. 58. The second position of the slides *b b'* corresponds to a vertical position of the larger axis of the eccentric, the crank being horizontal. The third position *c c'* corresponds to another horizontal position of the eccentric. In the fourth position of the slides, the eccentric brings them back to *b b'*, as in the second, and in the position of the eccentric and crank shown by *d d'* (fig. 58.)* If we observe the course of the piston-rods at each semi-revolution of the crank, we may make the following remarks:—

When the crank is horizontal, for example, at *o a*, the piston is at the end of the stroke; during the course of the crank from *o a* to *o c*, the piston runs over nearly half, or exactly $\frac{11}{20}$ths, of its stroke. The crank at length runs the second quarter, taking the position shown by *o e* immediately the piston accomplishes the second half, which is $\frac{9}{20}$ths of its stroke, passing to the other end of the cylinder. The same effect is produced, but in an inverse direction, when the crank turns the lower semi-revolution, and returns to the position *o a;* we may then conclude that, while the crank is passing from the horizontal to the horizontal, the piston makes one entire

* When we treat of the advance of the slides (39), we shall show that the horizontal and vertical positions of the axle of the eccentric do not correspond to each other exactly.

stroke, receding when the crank is passing from *o a* to *o e*, and advancing if it is passing from *o e* to *o a*.

When, on the contrary, the crank is vertical, as at *o c*, the piston is nearly in the middle of its stroke, and the crank, in passing to the horizontal position *o e*, brings it to the extremity of the cylinder; then, while the crank is again becoming vertical at *o e*, it brings the piston to nearly the middle of its stroke with a movement the opposite to the first. The effect is similar, but reversed for the other semi-revolution; thus the crank, in passing from the vertical to the vertical, makes the piston perform two half-strokes in opposite directions, the distances run being equal in both cases. If we carry on our observations, we shall find the same system with the movements of the slides in connexion with those of the piston. The eccentricity being, in fact, perpendicular to the axle of the crank, when this is horizontal, it causes the piston to run over the shortest distances—at which time the axle of the eccentric will be vertical, and will have the effect of making the slides run over the longest distances; so that, while the crank passes from the position *o a* to the position *o e*, and enables the piston to accomplish an entire stroke in passing from the horizontal to the horizontal, the eccentric will pass from the vertical to the vertical, and cause the slides to make two half-courses, one advancing and the other receding; or while the crank runs the first quarter *o a e*, the distances passed over by the piston go on increasing; and at the same time that the eccentric is running the quarter *o f h*, the distance run over by the slide diminishes. The greatest speed of the engine, therefore, corresponds to the least speed of the slides.

As the greatest speed of the piston takes place when its crank is vertical, the eccentric will at this moment be horizontal, and therefore will lead the slide very slowly; but as the slide will already have accomplished the greatest part of its course, the port of introduction being nearly entirely uncovered, it is of consequence that it should thus rest, in order that the

velocity of the steam of the port in communication with the steam-chamber, may be sufficient to establish the same force in the cylinder as in the boiler.

We will now refer to the relative movements of the pistons and of the slides.

If an eccentric and a crank be placed square with each other on an axle, they will effect two different rectilinear movements. As the crank passes from the horizontal to the horizontal, it impels the piston with a rectilinear movement in the same direction, and the eccentric, in passing at the same moment from the vertical to the vertical, imparts two rectilinear moments in two opposite directions to the slides.

While the piston performs the first of these movements, the slide accomplishes the two others; it advances and returns again when the port that it is connected with is successively uncovered and recovered; while, on the contrary, the piston performs two semi-revolutions in opposite directions, the slides effect a rectilinear movement in the same direction.

Therefore, while the velocity of the piston increases with each of these movements, the speed of the slide decreases, and *vice versâ*.

37. *On the Movements of the Crank.*—We shall now explain that the maximum space run over by the piston-rod corresponds to the minimum passed over by the slides, which arises entirely from the axle of the crank being set perpendicular to the axle of the eccentric. This geometrical figure gives the relative positions of these two contrivances during a semi-revolution of the crank; it is further evident that these positions are repeated, but in an inverse direction, in the other semi-revolution.

Let us suppose the crank in the position $o\,a$, fig. 59, (plate 33,) and $a\,a$ the length of the connecting rod; when the crank arrives at $o\,b$, the connecting rod takes the position $b\,b'$, and the distance run by the driving-axle is proportional to the distance $a'\,b'$; when the crank is at $o\,e$, the connecting-rod has taken the position $c\,c$, and the distance run over is proportional

to the right line $b' c'$. We see by the lines of the figure that the distances run over go on increasing; and it is evident that this progression would exist equally if we were to take an indefinite number of positions instead of only taking three—and if we made these distances to vary slightly by degrees, we should find that the crank would pass successively in the same manner by the positions $o\,e$, $a\,d$, $o\,e$, the connecting-rod passes by the right lines $c\,c'$, $d\,d'$, $e\,e'$, and that the distances run over are proportional to the right lines $c'\,d'$—$d'\,e'$, and which go on, as it is shown, diminishing.

Therefore, when the crank passes from the horizontal to the vertical, the distances run over by the piston go on increasing; and in passing in the contrary direction, from the vertical to the horizontal, the crank causes the piston to run over distances which go on diminishing; so that the greatest space run by the piston corresponds to the vertical position of the crank, and the smallest space to the horizontal position.

As regards the eccentrics, let us suppose its centre to be at f, and the rod of transmission attached at this point, which is exactly as if the position of the eccentric itself was shifted. While the crank is horizontal, the larger radius of the eccentric will be vertical, (supposing we do not notice the little deviation that it requires to take in front to form the advance of the slide); then the rod of transmission will be following the right line $f\,f'$. With the position $o\,b$ of the crank corresponding to that of the larger radius of the eccentric $o\,g$, the rod of transmission will be at $g\,g'$; the distance passed over by the slide is proportional to $f'\,g'$ or to $f''\,g''$, or equal to the projection $f'''\,g'''$. When the crank is at e, the eccentricity is at $o\,h$, the rod of transmission at $h\,h'$, and the distance run over by the slide is proportional to $g'\,h'$, or to $g'\,h''$, or equal to $g'''\,h'''$. Finally, when the crank turns the quarter of the circle $o\,c\,e$, the eccentricity describes the quarter of the circle $o\,h\,i$, and the extreme points of the rod of transmission pass again by the points $h'\,g'\,f'$. We see, then, clearly, by the figure, that while the spaces run over by the piston-rod are increasing, the spaces

run over by the rod of the slides are diminishing, and *vice versâ* in the same degree; so that when the axle of the crank and the axle of the eccentric are at right angles, the smallest space passed over by the one, corresponds to the greatest space run over by the other, and *vice versâ*.

This inverse motion, which we have so fully described, originates from the necessity for changing the distribution rapidly when the piston passes to the dead point, and changes the movement, and for leaving the slide, on the contrary, almost immoveable, and the openings as large as possible, when the piston acts efficaciously, and moves at its greatest velocity.*

38. *On the relative Movements of the two Cranks and the two Eccentrics.*—Now that we have observed the action of one eccentric with the crank in connexion with it, (fig. 59,) let us examine the relative positions which are taken by the two cranks and the two eccentrics, fig. 60, (plate 34.) A and B show the relative positions of the two cranks. A′ and B′ represent the relative positions of the two eccentrics. The eccentric marked A′ corresponding to the crank A, and the eccentric marked B′ corresponding to the crank B. The figures explain these relative movements sufficiently. We have before stated that a crank does not transmit an uniform movement, it finds a difficulty at the dead points, which are only overcome in stationary engines by the aid of fly-wheels. When there are two cranks on the same axle they are placed at right angles with each other, that, while one is passing at its minimum speed, the other shall be moving at its maximum; but it would be erroneous to suppose that this rectifies their irregular movement. The time when the velocity is at its maximum occurs when the two cranks are inclined to the horizon under an angle of 45°. Thus, let O A and O B, fig. 61, (plate 35,) be the two cranks set at right angles, the posi-

* The pressure of the steam on the piston being constant, the motive force is proportionate to the distance passed over, or to the speed; the greater the velocity the stronger will be the traction of the wheels.

tion O B′, O P′ will correspond to the greatest space passed over. The distances passed over by each crank will be represented by the projections of its radius horizontally; then the distances run by the two cranks O A′—O B′ will be double the right line O C. We know that the right line O A′ being 45°, the two angles O A′ C and C O A′ are equal; then the sides O C and C A′ are equal.

It is sufficient, then, to show that A′ B′ is greater than the amount of projection of the two cranks, whatever position they may be in. It is evident at commencing, where one is horizontal, and the other vertical, for the amount of projection is then equal to the radius; and it is also evident that, in the triangle O C A′, the sum of the two sides O C—C A′, is greater than the third. If we take another position, O A″—O B″ the sum of the two projections, or the distances passed over to O D—O E will be less than A′ B′. In fine, O E=A″ D and O D=E B″, if we join the point A″ to B″, A″ B″ to A′ B′; and it is further evident that the two oblique lines, A″ i + B″ i, are greater than the two perpendiculars B″ E + A″ D. We have, therefore, demonstrated that the positions O A′—O B′ of the two cranks, gives the maximum distances passed over by the rectilinear horizontal rods conducted by them.

It is moreover evident, since the sum of the projections O D—O E is greater than the radius, when the sum of the distances passed over both in the horizontal and the vertical position of the cranks is at the minimum. The velocity passing from the maximum to the minimum by insensible degrees.

This variation in the velocity exposes the engine to shocks and irregularities which are sensibly felt when it starts, but the weight propelled being considerable, effectually steadies and regulates the motion.

With respect to the relative velocity of the two cranks and the two eccentrics, they are precisely the same as those we have described for a crank and its eccentric.

As the slow movements of the slides correspond to the

rapid movements of the pistons, so this maximum speed of one of the pistons corresponds to the slow movements of the other; and it is *vice versâ* with the eccentrics.

39. *On the Lead of the Slide.*—We have explained that, at the dead point of the crank—that is to say, when its radius is blended with the axle of the cylinders, the slides should be in the middle of their course, and, consequently, the eccentric ought to be set square on the line of the axle of the bar.

It is necessary, in the construction of locomotive engines, to follow the rule of inclining the radius of the eccentric slightly in advance, in such a manner, that while passing the dead point the slide shall have already passed the middle of the course. The distance which it passes beyond the middle point is called the *lead of the slide.*

The result of this modification of the distribution is to increase the power of the engines, by enabling them to conduct the same trains at a greater speed.

If we consider a train at the time of starting, or on a part of the railway where it is necessary to employ the entire power of the steam, and to go very slow, the lead of the slide has the effect of diminishing the power of the engine; but this is not, however, exactly a proper, comparison we must consider the engines running with their normal speed, and with their power on the cylinders reduced; for if it is proved that, with the same train, the same engine acquires a greater speed when it has a lead to the slide, it is evident that its power is increased, and that it could draw a much greater load at its former speed.

This contrivance (lead of the slide) is almost exclusively applied to passenger-engines, which require to run with a speed of at least twenty miles an hour, or even thirty or forty miles an hour.

Proper experiments require to be made, with the necessary calculations, for ascertaining the effects of the lead of the slide for great velocities.

When the slides are not properly arranged, *i. e.* when the

overlap is not sufficient, the lead has the effect of opening the ports of escapement and introduction too soon.

The steam, therefore, commences its escape before the piston has terminated its stroke, and the steam from the boiler also operates on the piston in an inverse direction to the movement. Thus, there is at the commencement a resistance to the steam which diminishes the power of the engine, and, therefore, reduces the weight which it can draw. The experiments of M. De Pambour on the inclined plane of the Liverpool railway, with leads of 1-8th and of 5-8ths of an inch, have quite demonstrated the fact; some trains, which were stopped with a lead 5-8ths of an inch, were put into motion with a lead of 1-8th. When in a state of rest, the lead diminishes the power of the engine; but when the speed requires to be great, time completely changes the results, as we shall show.

In order to appreciate the advantages of the lead of the slide, it is necessary to allude to the inconveniences attending the ordinary distribution of the steam without a lead. In comparing the surfaces of the section of the ports with the spaces successively passed over by the piston, it is found that the ratio of the velocity is generally from 1 to 10. If we take into account the contraction and irregular velocity of the piston, we find that the velocity of escapement of the steam is from 75 to 85 yards per second, as a maximum, for a speed of 39 miles an hour. The velocity always possesses an initial pressure: we found, in our last inquiry, that 1-50th part of an atmosphere was sufficient. The difference in force between the cylinder and the principal steam-pipe is then insignificant, but it would not matter if it were more considerable, since the generation of steam at high velocities is not capable of maintaining other than a reduced force in the cylinder, and there is always a reduction by the regulator. The latter reduction occurring from the distribution would not, however, have any effect, since it could be obviated by opening the regulator a little wider.

The subject becomes very different immediately after the

escapement of the steam. Before the escapement obtains the maximum velocity of 85 yards, which, as we have before stated, offers very little resistance, it is necessary to pass off all the steam which maintained the high pressure. This considerable quantity of steam must be got rid of the moment the engine commences running, but it creates a resistance before the piston, very considerable at first, and which diminishes, more or less rapidly, according to the time that is given it to escape. If the strokes of the piston are very rapid, the steam sometimes takes a third of the total time of the stroke to escape. This occurs with a speed of 39 miles an hour, supposing the cylinder is full of steam, of an effective pressure of 2·75 atmospheres. The effect of this resistance is equal to the pressure, at each instant multiplied by the distance passed over by the piston; and in the case just cited, the piston having passed 3-10ths of its stroke before it could be cleared of this excessive pressure, and taking the mean resistance, it is found that it amounts (at the most) to a quarter of an atmosphere!

The resistance produced by the port of escapement is very considerable at high velocities. The lead of the slide is introduced to diminish this resistance; the escape continues an equal time, but the pressure maintained at the commencement is exerted in a proper direction on the piston; and on the return of the latter, although the steam is in part detained, the opening of escapement being sufficiently large, its influence does not equal more than a fraction of the stroke of the piston.

The resistance produced in the blast-pipe is also greatly reduced by the emanation of steam from the port. The principal inconvenience of a motion without a lead is thus remedied. It remains, however, to be seen whether this diminution in the resistance is not balanced by other inconveniences, when the ordinary form of the slide is preserved; (that is to say, without increasing the overlaps in such a manner, that when the escape is open, the entrance of the steam on the other

side is open also.) The steam thus arrives in an opposite direction before the end of the stroke, and therefore acts like a break against the piston. The work lost in this case is equal to the pressure in the steam-pipe, multiplied by the distance passed over by the piston: the last being very small, the work lost is much less than the economy effected in the resistance due to the escapement.

The premature opening of the port affords the piston the entire pressure of the steam at the commencement of the stroke; but this advantage is of no consequence, since we have just shown that, in moving without a lead, there is not at any time a loss of force by the contraction of the ports of introduction.

The port opens sooner, and, therefore, shuts equally soon; and this premature shutting is extremely advantageous, because it diminishes the expense of steam, considerably without diminishing the work, with the greater lead (5-8ths of an inch), and without overlapping the slides. This steam is not intercepted until at 0·93 of the stroke; supposing that the stop is effective to the end, the work will only be diminished a 0·003. Thus 0·07 of steam is saved by losing only 0·003 of the work. The stop, it is true, does not completely effect this, since there is an opening for the escapement, but the pressure of the steam at high velocities is exerted in such a manner as to diminish the total work of the piston but very slightly.

To resume the subject, the lead of the slide effects a saving in the consumption of steam by cutting off the entrance of the steam sooner; and it increases the useful effect, by diminishing, and even turning the requisite force of the escapement to account.

The premature introduction of the steam sometimes possesses inconveniences, which, although far from counteracting the preceding advantages when the velocity of the action is considerable, ought, however, to be avoided.

It is necessary to make the overlap equal the lead of the slides, in order that the steam may not be introduced on the

piston at any other than the dead point. This plan possesses another advantage which must not be overlooked; it shuts the passage of the steam sooner, and thus economizes a certain portion without prejudicing the work, as we have already said, the pressure of the steam which it holds being equal, at the first instant, to its initial force.

We have shown the intention and advantages of the lead of the slide, but the lead requisite to obtain the highest results remains to be ascertained. This will evidently depend on the velocity of the action, and on the form of the slide itself.

Engineers have no general rule for the lead of the slide, but make it from 1-8th to 5-8ths of an inch; it is generally about 2-8ths of an inch.

The reason for these differences will be found in the preceding observations, as well as the utility of the slide, in compensating for the delays proceeding from the elasticity of the pieces employed in the transmission of the motion from the eccentrics to the slides, and the play arising from the wear of these pieces.

40. *Relative Movements of the Slide and Piston.*—We will endeavour to illustrate the relative movements of the slide and piston by a geometrical figure, supposing the lead of the slide to be as it is generally constructed. Let *a b* be the radius of the crank, *see* fig. 62, (plate 36), and *b e* the length of the connecting-rod; let us suppose the crank at the point *b*. If from this point, as a centre, with a radius equal to the length of the connecting-rod, we describe an arc of a circle, the point *c*, where this arc meets the piston-rod, will be the point where the extremity of the connecting-rod should be; if we continue the line from *c* to *d*, making the distance equal to the distance between the point of attachment of the connecting-rod and the centre of the piston, and set off horizontally on each side of *d*, half the thickness of the piston, we shall have the precise place which the piston ought to occupy at this moment. Let *e* be the centre of the eccentric, *a e* the

eccentricity, in order to ascertain the position of the lever communicating the movement *g h*—it is sufficient to observe, that when the greater axis of the eccentric is vertical, this lever will also be vertical; so that, by taking the length of this axis of communication when the lever is known to be in the same position as the eccentric, we find the length *e g* when the eccentric is in the position shown in the figure: it is thus easy to determine every line.

If the position of the eccentrics were disposed the same as in fixed engines, the points *e* and *f* would be confused together, and the larger axis of the eccentric would be exactly perpendicular to the crank *a b*; but in order to give the lead of the slide, it is arranged so that the radius *a e* shall attain the vertical before the radius *a b* is horizontal.

It is further evident, from what we have stated, that when the eduction port is open at the same time as the port of introduction, the section of the passage of the latter is smaller than the former.

41. *On the Machinery.*—The great desideratum, in the arrangement of the machinery of a locomotive engine, consists in the driver being able to direct its movements forward and backward, as may be required. These movements are effected by the employment of eccentrics, from two to four in number. There are never less than the former; viz., one for each piston-slide. The first locomotives were made with two moveable eccentrics. This system was soon found inconvenient, from the effects of wear and play; also the difficulty of changing the motion at high velocities, when the eccentrics are not so readily put in action.

Some engineers employ two fixed eccentrics, but without any lead to the slide, or the latter is adopted for the forward course only, some retardment being experienced in employing it for the backward motion. Hawthorn was the first to introduce four eccentrics, which forms a great improvement. Two fixed eccentrics, with a lead both forwards and backwards, has since been tried on the railway to St. Germain, the plan of which we shall hereafter explain.

42. *Jackson's System of Two loose Eccentrics.*—We will now describe the plan employed by Jackson, in his first engines with four wheels. A A A A are the frames directing the horizontal movement of the piston-rods, which are on the larger weigh-bars B B B B. The connecting-rod C communicates the movement to the cranked axle D, on which the heads of the eccentrics are mounted, a view of which is given in fig. 65. These two eccentrics communicate, by their rod E, with a horizontal shaft *o*, the front view and the plan of which are given in figs. 63 and 63^1, and the sides in figs. 64 and 66.

This shaft is supported by copper pillars, *p p*, and receives an alternate rotative movement, which is changed, by the eccentrics, into an alternating movement, in the slide-rods and the levers *l* and *l'*. The first receives the movement of the eccentric, and the second communicates it to the rod by means of the assemblage *a*.

The two moveable joints *b b* receive the vertical rods *c c*, which operate by cranked levers connected with the horizontal shaft *g*. These cranked levers forward the movement to two horizontal rods, which are each terminated by handles, *m m*, which are operated upon by the engine-driver. By drawing these handles towards him, he lifts up the rods of the eccentrics, and prevents their communicating their movement to the slides, whereby he stops the distribution, and consequently the motion of the engine.

The two eccentrics are placed at right angles, and are, therefore, separated by a quarter of a revolution: they move on the shaft by means of the lever of engagement L, (fig. 63), which is fastened on the shaft *a*, and is put into motion by the medium of the perpendicular shaft *b*, through the pedal *p*, which is within reach of the engine-driver. There are two iron collars, *c c*, on the cranked tree, one on each side of the eccentrics, which carry a small projection on the outer side. When the eccentrics are between the two collars, the shaft turns without communicating any movement to them;

but when the eccentrics are carried against either of the collars, and the projections from the former, by means of the lever of engagement shown in fig. 63, enter the holes placed in the steel plate or disc forming the eccentric, then both partake of the rotatory movement of the driving-shaft, and the steam is accordingly distributed to both cylinders.

Therefore, when the two eccentrics are pushed on one of the collars, the projection from it soon meets the hole in the side-plate, and the eccentrics are engaged. The same thing may be done on the other side, but the motion conveyed would be the opposite of the first, so that, when the piston is moving in one direction, with the eccentric engaged on one side, if we engage it on the other the eccentrics either gain or lose a semi-revolution, and the slides, which had moved a certain distance of their course, instead of continuing it, return back again. Fig. 65 shows a side and front elevation of the two eccentrics; A shows the section of the discs employed in the engagement; *a* is one of the holes in which the projection from the collar enters. In order to understand the change of movement, we must study the figures showing the relative positions of the eccentrics and the pistons. It will be found that, when the piston is in the middle of its stroke, the slide opens one of the ports, by simply changing the side of engagement; and the slides, after resting motionless during a semi-revolution of the cranked axle, are then put into motion against the steam, the eccentrics being engaged the other way. This change is accomplished during the running, merely by the pressure of the foot of the engine-driver on the pedal.

The driver also has two other handles, *m*, *m'*, (fig. 66,) at his disposal. These are fastened on the shaft *a*, which is supported on the pillows *p* bolted to the fire-box. This shaft carries a small balance-bar, *b*, furnished with joints at each extremity, which conduct the rods *t t* passing to the front of the engine, and which partake of the movement of the draught of the eccentric by means of balances similar to *b*. The shaft *a* receives the alternating movement by means of two con-

trivances similar to *t t*, situated one on each side the engine; and the two curved levers receive handles which turn independently of each other—one in one direction, the other in another; so that the relative movement of each agrees with the movement of each slide. These two handles serve to change the movement of the slides by hand, after having disengaged the eccentrics, and to reverse the movement of the engine. Thus, if any accident happens to the eccentrics, the driver can work the engine by hand, in which case it is necessary to lift up or disengage the eccentric rods, the same as explained for stopping the engine.

Fig. 64 also shows the end of the lever employed to lift up and disengage the eccentric rods.

When it is desired to change the movement of the engine, after being stopped, the driver exerts a continued pressure on the pedal, by which he frees the eccentrics from the cranked axle, and they draw towards the collar of engagement opposite the other one. He then reverses the position of the handles *m m*, and gives the eccentrics a half-turn, which immediately receive the pins in the other side, and consequently change the direction of the movement.

43. *System with two fast Eccentrics.* — The system with two loose eccentrics, which we have just described, has been abandoned by engineers—the motion of the eccentrics being, from its delicacy, very liable to get out of order, and to impede the course of the engine. These defects led to the substitution of two fast eccentrics on the cranked axle.

The eccentric E, fig. 67, (plate 39,) fixed on the cranked axle A, is terminated by a cross. It communicates the movement to the slide-rod T, by the assistance of the small balance-beam C, which turns on the fixed point O. The balance-beam has two pivots, D D′, one at each end, which play in the two circular cavities L, by which the balance and the slide-rods partake of the movement of the eccentrics. The figure exhibits the position of the levers in passing backwards in the direction of the arrow F; the handle, at the command

of the driver for changing the movement of the slides, is raised and turned by the side of the fire-box; in proceeding forward the engineman lowers the handle by means of a double joint, and the eccentric-rod is raised by a crank piece, by the help of the roller G turning in the guide H. The cross, therefore, leads the balance-beam O C by its small axle D', and by shifting the slides changes the direction of the movement of the engine. When the motion of the engine is required to be changed, the position of the slides should be modified; so that, when the slide on one side is at the end of the course, that on the other side ought to have returned to the end of the course; the inclined planes at the seat of the cross are intended to effect this, by taking up the button of the slide-levers and slipping it into the seat prepared for it. Great force is requisite to overcome the friction of the two distributions. The large handle serves to move the slides, and thus to change the movement of the engine, but it will not enable the engineman to run the engine by hand, which is a disadvantage in engines with one handle only; but they are more easy to conduct in passing the turn-tables. The vertical handle is employed to stop the engine, and the feet of the cross do not give any movement: the balance-beam is neither raised nor lowered, but remains in the middle.

It is necessary in this system, in order to regulate the distribution equally for running forward and backward, to place the crank at the dead point, and to wedge up the eccentric on the cranked axle, so that its radius of action shall make a right angle with the middle line A O. The angle O A D which the eccentric makes in each position, with the bars engaged above and below, will give the quantity which the slide differs from a true course. The distribution will, therefore, be advanced or retained accordingly as the eccentric is fastened before or behind the crank. It is shown with an advance on two sides in the engraving. If, on the contrary, the crank were above it, there would be a retention on two sides.

44. *Stephenson's System with four Eccentrics.*—This difficulty led engineers to adopt a system which allowed the slides to have an advance before and behind. Hawthorn tried a third system, with four eccentrics, which was afterwards used by nearly all manufacturers. Jackson has employed it, with some modifications, in his new six-wheeled engines. Fig. 68, (plate 40,) shows the mode of arrangement adopted in Stephenson's six-wheeled engine.

The two eccentrics $e' e''$ are employed to move the machine forward; and the two others $f' f''$ to move it backwards. These two systems form two to two, at right angles with each other; the two eccentrics of each pair are also placed at right angles, but the two systems form an angle between them, which is less than two right angles, equalling the sum of the advances. The two eccentrics $e' f'$ communicate the movement, by means of the axle $i' i'$, to the slide-rod of the cylinder on the left, and $e'' f''$ communicates the movement by the same axle, $i' i'$, to the slide-rod on the right. An elevation of the eccentric-rods, and of their levers of transmission, is given in figs. 69 and 69^2, (plate 41,) in two different positions. The eccentric-rods are terminated by forks $g' g'$, with a notch at the angle, separating the two branches of the fork.

These notches are intended to receive pieces which we call handles, and which they become united with when the movement represented in fig. 69^2 is required to be made. Fig. 69 shows the position of the eccentric-rods at the instant they have ceased to act, that is to say, when the engine is stopped. The handle is joined with the levers, and fastened on the axles $i i'$ (fig. 70.) The latter turn in brass carriages, fixed on the frame of the engine, which are made in two pieces, like ordinary supports, and fixed by bolts on the large weigh-bars. They are tightened as the copper wears. The levers $b b'$ are fastened on the same axle: they are of the same length as the levers $h h'$, and the slide-rods m are connected with them by tenons and mortices, secured by bolts, which permit of a vertical movement equal to the curve of the arc described by the

lever *h h'*. The other end of this horizontal rod is fastened to the head of the axle of the slides in a similar manner.

As the forks of the eccentric become attached to the handles, they impart an alternating movement to the crank-arms *l l'* and the levers *h h'*, and which convey it to the slides. The levers *l* and *h* being of similar length, the course of the slides is, therefore, equal to that of the eccentrics. The horizontal movements of the slide-rod correspond to the oblique motion of the eccentric-rod, while the levers and crank-arms describe an arc of a circle, as described by the plates. The seatings of the forks and of the levers are constructed of steel, to enable them to resist wear. The whole of the joints connecting these pieces are required to be free from play and elasticity, since the regularity of the action of the piston depends on their relative immoveability.

The eccentrics *e' e''* are placed at right angles, in order that their greater axles may also be at right angles, in connexion with the cranks, corresponding to the pistons which they work; and they are placed a quarter of a revolution in advance, that the port of introduction may be opened when the piston is in the middle of its stroke. They are so placed, that the piston-rod forces the engine along by pushing the axles when they are below, and by drawing it when above, so that the wheels proceed, following the curve, and carry the engine with them.

The two other eccentrics are employed to move the engine backwards, the particulars and details of which are exactly similar to the former eccentrics. The forks take the two extreme handles *n n'*, instead of the two handles *h h'* (fig. 70.)

The axle *i* communicates its alternate rotative movement to the shaft *j* by means of the lever *p*, (figs. 69 and 69[2].) A small crank-arm, furnished with two eyes, *s t*, is fastened to the axle on the latter; and a long rod, with a handle, *m*, is connected with the former, near the driver of the engine. It is by means of this handle that the engine is moved backwards or forwards, or stopped. In order to prevent the eccentrics acting upon the

slides, the lever *n*, which is connected to the axle *c* by a joint, is lowered, and the seatings on the forks are thrown out of gear with the handles, and, consequently, with the slide-rods.

Fig. 69 shows the handle in the midway position M', when the slides are in a state of repose; and fig. 69², gives it in the position M, that is to say, moving the engine forward. This handle is, moreover, fixed in the position required by a proper guide, &c.

When the engine is stopped, the handle assumes the vertical position M', and the levers *s* and *p'' p'''* are horizontal: the eccentrics are all dislodged, and merely move the levers *n n'* round their point of rotation *c*, without acting on the slides; the other eccentric rods are also supported by similar levers. The distribution, however, being stopped, the engine would merely continue in motion from the impetus it had acquired. When the hand-lever is brought to the last notch of the stop, the positions of the levers of the eccentrics are changed, the lever *p'''* rises, and takes the position *p* (fig. 69²), by moving round the turning point *j*. The lever *p''* is, on the contrary, lowered to the position *p'*, and retains the eccentrics for backing; so that their notches do not engage the axle *a*, or the lever of the advance-movement.

When, on the contrary, the hand-lever is brought into the position M'', the rods of the advance-eccentrics *e e'* are disengaged, and the others, *f f'*, are put in connexion with the driving-axles of the slide-rods. We see, then, that the engine takes either a forward movement or a backward movement, simply by placing the hand-lever before or behind. The movement of the axle *i* is communicated to the axle *j* by means of the lever *p* (fig. 69²); and this axle *j* is itself in connexion with the rod with the handle T, which the driver has at his disposal. These rods, which are put in movement by the eccentrics, occasion some friction in the engine. It will be perceived, that, in this system, the eccentric-rods are suspended to levers and to vertical pieces, attached, either directly or indirectly, to the lever for changing the movement. This affects

their solidity, so that the seatings on the forks are liable to break away from the handles. Some engineers have, therefore, placed the lever of the eccentrics above the axle of communication, with the forks in an opposite direction, so that the forks press on the axles with all their weight during the movement. But this arrangement is open to serious objection: for if the rods of the eccentrics, opposed to those which are in movement, should by accident fall on the axle, fracture would be very likely to arise, whereas this could not occur with the former plan.

This arrangement is adopted by Stephenson and other engineers, with various modifications in the communications of the movement. The employment of a single lever to change the direction of the engine, by altering the order of the introduction of the steam, is convenient, but it presents the inconvenience of not permitting the engine-driver to work the slides by hand for short distances, if an accident should happen to the eccentric-rods.

It is unnecessary to state, that the lead of the slide can be arranged, by this system, for the forward as well as for the backward course, by making a sharp angle in the connexion of each eccentric with the corresponding crank.

45. *Jackson's System with Four Eccentrics.*—An arrangement with four eccentrics has also been adopted by Jackson in his new six-wheeled engine, *La Versailles* (fig. 71, plate 42). A shows the side-elevation, B the plan, C the front elevation. The principle of engaging and of disengaging is the same as Stephenson's. The forks of the eccentrics communicate the movement to the slide-rods *t*, by means of guides *o o'*. The driver of the engine changes the movement from a forward to a backward course by raising the pin *d*, which holds the lever; the spring which secures the pin then rises, and the engineman draws back the handle M to the position M'; the pin *d* is again applied, when the handle is fixed immoveable in the notch. During the passage of the handle M to the position M', the rib T acts on the crank-arm *e''*, turning on the shaft *p*,

also on the double one $e e'$. The extremity of the crank-arm passes from f to f, the extremity g of the lever e' goes to g', also the two levers $g h$, $g j$ go to $g' h'$, $g' j'$, while the extremity k moves to p', and the two levers $k l$ and $k m$ pass to $k' l'$, $k' m'$, so that the eccentrics which were originally engaged are disengaged, and *vice versâ;* the direction of the movement of the engine is then changed; since the eccentrics are two to two, there is a loss of a semi-revolution.

When the handle M is placed in the middle notch, the double lever $e e'$ is horizontal, the four rods $g h$, $g j$, $k l$, $k m$ are vertical, and the four eccentrics are disengaged. This system possesses the advantage of being more simple than Stephenson's. It is also composed of stronger pieces, is less liable to vibrations arising from elasticity, and is therefore more precise in its action.

We have already stated that the notches in the forks were for the purpose of regulating the distribution in a symmetrical manner, and changing the direction of the motion. When in the midway position, the notches do not act on the distribution, they ought, therefore, to be at a distance, so that, in the alternate movement, when they receive the eccentrics they shall not meet the handles of the slides, however they may be situated.

46. *System of Four Eccentrics employed at Haigh Foundry.* —The system employed at Haigh Foundry is not very different from Stephenson's and Jackson's. Fig. 72, (plate 43) gives an idea of it. The balance-beam A turns round the fixed point o, gives the movement to the slide-rod T, and receives it by the notches on the fork. The two eccentrics B are engaged, and the two others B′, which are employed for the backward course, are not.

The change of movement is effected by means of a lever, C, furnished with a handle, M. The three positions which the handle takes are regulated by the rod D, which is furnished with three notches at the end, and play on an axle G, situated

at the end of the engine, which, being beyond the reach of the driver, is evidently an inconvenience.

This arrangement is very much like that of Jackson's new engine, and, like all the other systems with four eccentrics, affords a lead both forwards and backwards.

47. *Theory of the Distribution with Two Fixed Eccentrics.*—The change of movement with two fixed eccentrics is made after the same plan as that previously employed with engines used for mining purposes, by re-attaching the eccentric rod to the opposite side of the lever of the slide.

If the system of securing the eccentrics on the lower lever for the forward course were continued, the distribution would experience delay on both sides, as we will explain. Let $o\,g$ (fig. 73, plate 44) be the crank at the dead point, &c. and $c\,b$ the lever of the slide, and let us suppose that the eccentric rod is fastened at c for the forward course (curve f), and at b' for the backward course (curve f').

It is necessary, in order that the eccentric may be securely fastened, that when the crank is at the dead point, the radius of the eccentric should be square with the eccentric rod; (the position of the latter varying) the proper position would be at $o\,a'$, and the radius of the eccentric would be placed at right angles on the centre line $o\,a$.

When it is desired to move the engine forward, the eccentric-rod being represented by $o\,c$, the eccentric should be at $o\,c''$, at right angles with $o\,c$, instead of which it is at $o\,a'$; it will therefore be delayed, the crank moving in the direction of the curve f.

In the backward course of the engine (curve f'), $o\,b'$ being the eccentric-bar, the eccentric ought to be at $o\,b''$, but it is at $o\,a'$: thus, there is the same quantity lost with this movement, the quantity represented by the angle c'', $o\,a'=a'$, $o\,b''=b'$, $o\,a=\frac{boc}{2}$.

In order to have the lead suitably arranged, it is necessary to place the eccentric at t''; a lead is then given to the forward

course by the angle t'', $o\,c''$; but the delay in the backward course is also very considerable, which is represented by the angle t'', $o\,b''$.

A lead may, however, be obtained in both directions, by placing the eccentric bar at b' for the forward course. The eccentric will then be fastened at a', (fig. 73) for the normal march; the lead for the forward course would be represented by a', $o\,b''$, and the backward by an angle equal to a', $o\,c''$.

As this lead is generally insufficient, it may be doubled without causing any retard in the backward course. It is for this reason that many engineers shorten the eccentric rods and increase the length of the levers of the slides. They are thus enabled to obtain a considerable lead in each direction (fig. 74, plate 45.)

The inclination of the eccentric-rod presents an inconvenience which is too important to be passed over. If, by any cause, the spring supporting the boiler descends or rises, the movement which the eccentric-rods convey to the slides has the effect of deranging them. Thus, if we inquire what would be the movement of the slides for an oscillation of ·79 of an inch of the spring, we shall find it would amount to ·079 of an inch with the distribution shown in fig. 67, and to ·138 of an inch with the distribution shown in fig. 74. We have even found it to equal ·315 of an inch by another arrangement, in which case the irregularities resulting from it would be very injurious.

This effect is explained by fig. 73[2]. Let us suppose that the axle lowered itself to o, the eccentric-rod would take the position $o'\,b'''$, and would derange the slide to an extent equal to $b'\,b'''$.

48. *Mr. Cave's System, with Two Fixed Eccentrics.*—We have already shown the possibility of having a lead both backwards and forwards with two fixed eccentrics, depending on the angle formed by the rods of the eccentric in their two extreme positions.

We have already stated that, until the present, this angle

has been quite insufficient. Mr. Cave shortened the rod of the eccentric in his first locomotive, and increased the length of the levers of the slides, so that the angle of the lead averages 15° for the course forwards and backwards. This angle may even amount to 30° for the forward course, without causing any retard to the backward course.

The system of distribution is indicated in figs. 74 and 74², (plate 45.) The lever of the slides *a a'* turns round a point, *o*, placed at the level of the axle of the cylinder, so that the inclination of the two bars is the same; and the inconveniences of this inclination are thus reduced to a minimum.

The eccentric is connected with the upper handle for the forward course.

It may be remarked that the lever of the slide fills the same office as the feet of the fork, by means of its curved form; the handles, being fixed to the eccentric, force the slide to shift by acting on the lateral curves,* when the movement is reversed.

We may observe one great advantage of this distribution, viz., the re-covering the slide for the introduction of the steam. It opens the entrance-port at the commencement of its course only, and shuts it well before the termination. The port of escapement is opened prematurely, and cleared of a quantity rather less than that which is given by the lead.

49. *Hawthorn's System.*—The whole of the engineers whose methods we have at present examined, employ eccentrics for the distribution, notwithstanding this system is said to present the inconvenience of being too feeble. Hawthorn at length introduced a change in his engines, (*see* fig. 75, plate 46;) he makes use of the same movement—viz., the connecting-rod—to distribute the steam to the slides.

A roller A terminates the connecting-rod B, which turns in

* This arrangement has been modified. The foot of the fork has been since placed upon the eccentric rod, and its branches increased to suit the arc described by the intermediate rod, which is longer, and answers, moreover, for a more extensive run of the slides than is usual with locomotive engines.

the rectangular guide-piece C. This piece passes up and down during the rotation of the connecting-rod on the cranked axle. The point D C describes a portion of the circumference, and the movement is communicated to the point F, where it is changed into an alternating movement. It is thence conveyed to the slide-rod, by means of the lever E F and the cross G. The figure represents the position of the pieces for the forward course. When the movement is required to be changed, the handle M is put in requisition. If the engine-driver brings it vertical, the whole is disengaged; the piece B then takes up a position in the middle of the balance E F, and does not engage either with the point E or the point F. When the handle has passed the vertical, it makes an angle with it equal to that which it made on the other side, as shown by fig. 75, then the points H and I describe arcs of a circle; the rod J rises, and brings the seat of the cross G to the upper part of the balance E, this movement taking place while the crank makes one revolution, by which the movement of the slides is suddenly changed, and the direction of the engine is reversed.

It is requisite, in order to obtain a lead for the forward course, to fix the length of the lever L so that the piece C shall open the port of introduction before the piston arrives at the end of its stroke: thus, as the crank is represented horizontal in the figure, the piston is at the end of its stroke, and the port of introduction has just been opened. As respects the backward course all is symmetrical, since it is evident that this method allows of an advance forward as well as backward.

Hawthorn has adopted a very ingenious method of increasing and diminishing the lead of the slide in several of his engines, which is founded on this system, and may be done in a few moments; it consists in increasing or diminishing the length of the lever L, and in fixing the point I farther or nearer the centre.

This system possesses an advantage over the eccentrics, in

having a more considerable element of movement. While the course of the eccentrics is not more than 2¼ to 2⅜ inches, the connecting-rod, on the contrary, makes a vertical course at the point A, from about 10 to 11 inches. It therefore results, that the loss of movement arising from the play, wear, and elasticity of the movements, is much greater in the eccentric system than with this.

50. *On the Outer Frame.*—The engine is supported all round by large exterior sleepers, consisting of ash-wood, (*see* fig. 76, plate 47.) The sides *n* are about 3 inches thick by 7 inches deep, and are covered with wrought-iron plates, ¼ of an inch in thickness, which are fixed by iron bolts properly riveted. The four pieces of wood are joined by tenons and mortices, and the corners are secured, both outside and inside, by wrought-iron angle-irons, bolted together. The fire-box, boiler, and smoke-box, are fixed on this frame by iron supports, and strongly secured to the sides of the boiler by bolts, (*see* fig. 77.) Strong wrought-iron plates are bolted to the frame on both sides of the axle, which serve as guard-plates to them, and support the carriages in which the axles turn, and counteract the shocks which the wheels experience. The guard-plates of the driving-wheels have also to resist the horizontal shocks arising from the action of the cranked axle. The whole of the guard-plates are, on this account, joined together by iron rods, fig. 78, (plate 48), which are bolted directly to the frame at *a*. The guard-plates of the carrying wheels are also furnished with a connecting-bolt below, *b*, which joins each side together beneath the axle.

There is a chain at *g*, (fig. 79), terminated by a hook, by which the train is attached when the engine draws going backwards, and which is passed through a ring bolted to the frame. The rods *a a* (fig. 76) serve to join the tender with the engine, and are required to resist both pressure and compression. The wheels are covered, to prevent their throwing up the sand or dirt, which is attracted by their rotative movement, and which would dirty the axles in friction. The lon-

gitudinal frame is sometimes made of iron, and placed inside the wheels (fig. 79). Bury adopts this arrangement in his engines, the cross-piece lying at the end remaining of wood, the iron crossings are fastened together square by bolts; and the whole is secured by angle-irons. These crossings are in one piece, and the supports of the springs are fastened with overlapping bolts. This system has the advantage of taking up less room than exterior framing, but it presents greater inconveniences, which we shall refer to hereafter.

The piece *e* (fig. 79) is placed a short distance from the rails and in front of the engine, to throw off any stones that may be on the line. It can be fixed at any height, as it slides in the grooves *c c'*. The buffer *f* is filled with horse-hair, supported by spiral springs for the shocks. The guides G of the grease-boxes are fastened to the frame by bolts *b b'*.

Fig. 79[2] describes the design of the frame used by Sharp and Roberts, and which unites elegance with strength. The dimension in the direction of the resistance is $7\frac{3}{4}$ inches. This form was adopted to avoid the use of long guides, which are necessary for the carrying wheels, when the frame is horizontal. The frame, by this plan, joins each of the axles, and the guides are, therefore, uniform.

51. *On the large Cross-pieces or Weigh-bars.*—Fig. 80, (plate 50), shows the mode of securing these inside crossings, which are three or four in number. Those in the middle are sometimes divided for the driving-axle; they are constructed of wrought iron, and fastened to the inside casings of the fire-box and smoke-box. Figs. 80 and 80[2] exhibit two different systems. The first is employed by Tayler; a piece of iron surrounds the fire-box, with lugs set at right angles, to receive the crossings. The latter serve to secure the cranked axle to the cylinder-box, and to strengthen the several parts of the engine. They support the cranked axle in three or four places, as well as the two other axles, so that they are enabled to resist the lateral concussions, and the action of the piston in its stroke forward and backward.

The shafts connected with the distribution in Stephenson's engines are supported at four points by the weigh-bars. The latter are fastened to the fire-box and the smoke-box by iron knees, which are properly rivetted to the plates of the former, and to the cylinder-box.

The plates which are required to guide the piston-rods are bolted on these weigh-bars, which are often obliged to be inclined from the fire-box to the cylinder-box, in order to allow the cranked axle to pass. The weigh-bars are not made thick, (about $\frac{1}{4}$ of an inch,) but they are of great depth, (about $3\frac{1}{2}$ inches.)

Jackson has fixed the carriage belonging to the cranked axle to the fire-box, in his last engine, without prolonging the weigh-bar next the cylinder-box; but this plan appears to subject the fire-box to considerable shocks. We give a section of it in fig. 81: the iron frame A is fastened to the fire-box with rivets, and receives the guide B, with gibs and cottars. The weigh-bars are sometimes made of two small iron plates, joined like the guides of the grease-boxes; and the bearings are placed between them. The manufacturers frequently employ only one plate, and form an enlargement at the parts intended to receive the bearings, as indicated in figs. 79 and 80.

In Bury's four-wheeled locomotives the weigh-bars supporting the weight of the engine are placed directly inside the wheels, above the axles, which gives them an appearance of greater lightness, since the wheels are free on the outside. This plan, however, is prejudicial to its strength generally. The outside frame joins the sides to the front and back, and renders the engine stiffer when in motion. It is also of great assistance, in the event of the engine leaving the line—the destructive effects of which are much reduced by the strength of the pieces, and more especially by this frame. It is highly important, and even indispensable, that the engine-driver should have access to every part of the engine, even during the running; and when the wheels are covered with sand-guards, this frame forms a sort of plank, which the engine-

man uses to inspect certain parts, and to grease those which are subjected to much friction. The removal of the outside frame and weigh-bars is of no advantage in diminishing the friction. The cranked axle is never so firmly held when its supports are near the centre as when they are applied at its extremities, the parallelism being so much more difficult to preserve in the first case.

52. *On the Grease-boxes and Inside Supports.*—The guard-plates, which we have before referred to, and which are attached to the outside frame, receive the grease-boxes in which the axles turn. They are generally all alike (*see* fig. 82, plate 51.)

The apertures B'B' are intended to hold the oil employed to diminish the friction. The cavity C, in the centre, receives the rod which communicates the pressure to the springs.

Figs. 83 and 84 give the details of the boxes which receive the grease, according to Stephenson's practice, A A is an iron box, enclosed at the end and sides. The interior of the box A is octagonal, and receives the brass bearings, on which the gudgeons of the axles turn. A projection is made from the carriage at the middle of the gudgeon, which enters the cavity E, and secures it to the guides. The two brass tubes F F admit oil to the gudgeon, and are fastened with screws on the carriage itself; there are pieces of cotton in these tubes, which, being dipped in the oil, form siphons, and feed the gudgeon constantly in an economical manner. The bottom is enclosed by a piece of iron, and fastened to the piece A by bolts, H, (fig. 83[2]). The circular part of this piece C is not concentric with the gudgeon, and therefore does not touch it. The upper part of the grease-box is shut in by an iron cover, which serves to protect the oil.

Jackson makes the grease-boxes in the following manner, (fig. 84). All the upper part A is formed of copper, and the lower part, B, of iron, and they are secured together by a bolt.

The supports connected with the interior weigh-bars are remarkable for their wearing out in the two horizontal direc-

tions only, on which account these parts of the bearing only require to be tightened. The weigh-bars A A are enlarged at B (fig. 85), and a rod D unites the two cheeks of the enlargement C C, passing through a collar, which prevents their re-approaching. The two wedges E E upon each side serve to tighten the bearings when they are worn in a lateral direction; they present faces parallel to the bearings, and rub against the adjusting faces situated within the cheeks C. The bearings pass the wedges on each side, in such a manner as not to take any cross movement. The axle never presses vertically on account of the springs, which convey the pressure to the external grease-boxes and gudgeons. The upper parts of the two screws are furnished with two small cog-wheels, in which the spring R engages. The same plan is adopted when the bolts are submitted to great movements, to prevent their becoming loose. There is a fixed point in the middle of the spring, which permits it to act on each screw.

Fig. 86, plate 53, gives the mode adopted by Jackson in his four-wheeled engines.

a a is one of the plates forming a cross piece, which is fastened to another similar one, between which the bearings *b b* are placed. They can be tightened as they wear, by means of bolts *c c*. A system of double wedges, terminated by screws and double nuts, retains the bearings in their places. The plate *d* secures the two cheeks and receives the action of the nuts.

Fig. 87 gives a section of the grease-box generally employed for carrying wheels, and for the axles of wagons. A and B are the iron pieces, and *c* is the copper bearing on which the entire weight of the engine rests: there are bolts at D which join the two pieces A and B together. The axle never rests on the piece B.

53. *On the Springs.*—We have stated that the weight of the engine is conveyed to each of the axles by the springs. Those connected with the driving wheels are the strongest, and are composed of twenty steel plates, which are attached

above the exterior frame (fig. 88). The jointed levers *c b*, which yield to the movements of the engine, hold the springs and receive the weight of the engine. The springs of the carrying-wheels with flanges, are below the frame (fig. 89), and are held by levers united to the cheeks of the guides by bolts; a rectangular iron-piece is fixed in the centre of each spring, and is held by an inside bolt, extending to the grease-boxes, which thus support the entire weight of the engine, the wheels and axles excepted. This arrangement reduces the destructive effects of shocks very much, and the latter are very injurious at high velocities to every part of an engine.

The springs require to be made of a certain number of metal plates, of the best possible steel; they should be all joined two and two by small pins, let into one and entering a mortice placed in that which is immediately beneath it, which prevents any horizontal movement. The rectangular strap fastens the whole of these plates together. The springs must be uniform in elasticity. The first plate only ought to be curled at the ends, at *c c*, and fixed to the pins of attachment (fig. 88.) In many engines, more particularly in those made by Hawthorn, they are able to tighten the tension of the spring of the driving wheels at will, by which they obtain a greater portion of the weight of the engine, and consequently increase the adherence, since it is proportionate to the weight supported by the driving-wheels.

Buffers are fixed at the ends of the carriage-frames, which are filled with horse-hair, and intended to counteract the effects of shocks, when the engine meets another carriage (see fig. 79, plate 48). These buffers are at the same distances from each other, and at the same height, throughout the same railway. The meeting of two carriages, therefore, presents no inconvenience. The buffers of most engines contain a spiral spring, which renders their action still more perfect.

54. *On the Wheels.*—The wheels are of two kinds, and either four or six in number, according to the manufacturer. The first locomotives were constructed with four wheels, and

belong to that class of which Jackson's first engine may be considered the type. We have explained that six-wheeled engines are adopted on nearly all the present lines. These engines admit of the surface of the grate being increased, also the weight of fuel: they also partly correct the effects of the plunging, by assisting the driving with four other wheels.

These wheels require to be constructed in the most solid manner, since they support the weight of the engine, and transmit the whole of the action which produces the locomotion. The tire of each should present sufficient adhesion, and be able more particularly to resist the wear at the angle near the flange. It should be securely fixed to the spokes, which have to resist the effects of flexion and crushing. The spokes should be joined to the naves, which require to be strongly wedged on the cranked axle, so that these may appear one piece. In short, the cranked axle and all the several parts connected with the driving-wheels ought to be put together in such a manner that the whole may be perfectly solid, and capable of resistance at every part.

Stephenson makes the driving-wheels of his six-wheeled engines 5 feet in diameter, and without any flanges. The two other pairs are placed, the one pair behind the fire-box, and the other behind the smoke-box: these are made 3 feet 6 inches in diameter, and are each furnished with a flange on the inner edge to prevent their running off the rails. They are invariably wedged to the axles, which turn in the grease-boxes, already referred to, the same as the driving-wheels. The construction of these wheels is described by fig. 90, plate 54.

The driving and carrying-wheels are constructed after the same style. The diameter of the driving axle is about 6 inches, and that of the gudgeons of each of the three axles about 3 inches.

The naves are formed of cast iron; the diameter of that connected with the great wheels being 1 foot 9 inches, and of the smaller ones 1 foot 3 inches. They are each fixed to the

axle by four tightening keys, which fit four grooves formed in the axle, and nave. These four keys support the entire weight of the engine, and the wheels are readily and truly fixed by this system of wedging. The voids left in the nave are merely adopted to diminish the weight. The rims of the wheels F are formed of cast-iron, 4½ inches in thickness all round, and a void of 2½ inches is introduced. The lower cheeks C are intended to receive the spokes, which are of wrought-iron, 2½ inches in diameter at one end, and 2 inches at the other, and ¾ of an inch in thickness. They are twenty in number, and are fixed in the nave and the rim of the wheel in an inclined position, and cross each other alternately. This method affords the greatest strength to the wheel, and enables it to resist the effects of shocks and friction, by maintaining it in a vertical position. The ends of the spokes are covered with a layer of borax, in order to secure the connexion with the nave, and upon the openings being stopped, they are placed in the sand, in communication with the moulds of the rim and nave; upon the metal in fusion approaching these ends, the borax gradually becomes melted, and completes the adhesion. The nave is run first, and left in the sand about three quarters of an hour, when the rim is cast. This is necessary from the latter contracting so much more than the former in the cooling, on account of its larger size. This has the effect of binding the spokes to the centre; if, on the contrary, the rim and nave were cast at the same time the wheel would be liable to rupture from the unequal contraction of the parts. The iron circle, or tire I, serves to enclose the wheel. It is made of wrought iron, hammered, and rounded by the hammer to the diameter required, and welded together. The tires of the wheels (with the exception of the driving ones) are furnished with a projection or flange on the surface, which rests on the inner edges of the rails, The surface of the tire is conical, and, therefore, presents the same inclination as that given to each rail towards the centre

of each line of way. This contrivance also tends to keep the engine constantly on the way. The difference resulting from this conicity accommodates the engine at the curves, where one wheel requires to traverse a greater distance than the other connected with it.

The friction of the flanges against the rails is never continuous along the curves, although the former maintain the engine on the way. The tire of each wheel is put on in a heated state, and its contraction in cooling has the effect of binding the wheel together. It is important that all the joints of a wheel are firm, so as to be able to resist any change of form from pressure or shocks; but it is equally necessary in the operation of tightening by heat not to exceed the limits due to the elasticity of iron, otherwise the tires would break, after being a short time in use. The tires are fixed to the rims by bolts, with countersunk heads, and each pair are turned of exactly the same diameter.

The driving-wheels are larger than the others, and are frequently formed without flanges; those of the other wheels being considered sufficient to keep the engine on the way.

The wheels of locomotive engines were originally constructed entirely of cast-iron, but it was found difficult, or even impossible, to prevent unequal contraction in the cooling; they, moreover, were scarcely able to resist the shocks to which they were exposed. The casting was also rapidly destroyed at the angle made by the flange in friction with the rail; and it was observed that its adhesion was not equal to that of wrought-iron.

Wooden spokes have been tried on the Liverpool and Manchester railway, armed with iron, which were found to possess greater elasticity.

Fig. 91 (plate 55) gives the section of a carrying-wheel used by Stephenson, the spokes of which are in cast-iron, and placed in the casting at the time of running it. We have already explained that cast-iron does not offer sufficient secu-

rity on account of the violent shocks to which the wheels are subject. The keys for wedging the wheels to the axle are as many as four in number.

A wheel formed entirely of wrought-iron, with the exception of the nave, has been adopted by Jackson, which system, although expensive, has the advantage of great strength. The spokes are generally about twenty in number, and are wrought separately; the end which is let into the nave is slightly forked, which enables the metal forming the casting to take a hold while in a state of fusion. The other ends of the spokes, which are plain, and formed with a circular section, are split into two flat parts, and bent to the shape of the circumference of the wheel, (see fig. 92.) An iron circle, forming the rim, is placed on these curved pieces, and is united to them by strong rivets. The rim is directly enclosed, by an iron-tire, in the usual manner, furnished with flanges on the circumference. There are, also, five or six other rivets passing through the curves of the spokes, the rims, and the tire. The tire further covers the interior side of the rim, as may be seen by the section; but with a thickness of 1-10th to 1-7th of an inch only sometimes.

The wheels are sometimes made of a single piece of iron, the nave excepted, which plan is in every respect superior to others.

The diameter of the wheels of locomotive engines varies according to the nature of the work they have to perform. Thus, the driving-wheels of engines, employed in the conveyance of goods, constructed with great tractive power, and travelling at a slow rate of velocity, are 4 feet to 4½ feet in diameter. They are also coupled with the front wheels, which are of the same diameter.

The weight of passenger-trains being always limited, the driving-wheels of the engines employed in drawing them are of larger diameter than the former; they are made about 5 or 5½ feet in diameter: some engineers make them 6 feet, which it is not improbable will be generally adopted.

The increase in the diameter of the wheels is important as

it increases the speed. Brunel has made the driving-wheels of the locomotive engines, on the Great Western railway, 7, 8, and even 10 feet in diameter, the results of which have not perhaps been precisely what was expected; the speed, however, has been increased in a great proportion, since these engines have made several trips, with a weight of 40 tons, at a mean velocity, from 34 to 37 miles an hour.

The carrying-wheels of locomotive engines are generally three feet in diameter; some engineers have very properly increased the diameter of the front wheels of the six-wheel engines to four feet. This forms an improvement; as these wheels support a large portion of the weight of the engine, they have a powerful effect upon the way when of too small diameter.

55. *On the connexion of the Engine with the Tender.*—The fuel and water which are required by a locomotive always accompany it. These requirements are supplied by the tender, which is joined to the engine by a contrivance which allows of movements in every direction, (see fig. 93, plate 56.) This is indispensable, as the tender seldom follows direct after the engine. A is one of the pieces of wood of the outside frame. The iron plates *i d e* receive the pin *i*, which passes through the connecting bar *b g h*, the latter being terminated at each end by a pin-hole: the pieces of plate-iron E E extend the entire length of the tender. Fig. 94 shows the mode of connexion employed by Stephenson; the difference between this mode of joining and the preceding, consisting in one being only taken to the fire-box, while the other is secured to the frame.

The feed-pumps, which connect the engine with the tender, are attached to the feed-pipes. These pipes have been made both of leather and caoutchouc, but these were not sufficiently strong. It was found, moreover, necessary to substitute metal, in order to be able to return the waste steam to the tender. They are generally made of copper, and disposed so as to be capable of moving in every direction.

Jackson, and other engineers, employ the adjusting-pipes shown by figs. 95 and 96, (plate 57.) The two spheres *a b* form joints, and permit of any movement. The pipes *c d* have a particular joint. A piece *e* receives the pipe *d*, which is screwed into the former. The pipe *f* passes along the inside of the pipe *g*, and rubs against the guides *i i*, and admits of a movement perpendicular to the section of the pipe itself. The lugs H serve to suspend the pipe to the engine or platform, by which the different movements which the pipe requires to take are not affected.

On the arrival of the engine at the terminus, the driver sometimes requires to detach it from the tender. It is, therefore, necessary to employ some ready way of accomplishing this. The holding-pin is soon removed, since it is merely secured at the lower part by a key. One of the screw-collars *e* is then unscrewed, and the tube *d* is separated from the tube *c*; this collar rubs along the pipe at *p*, and buts against the projecting part which forms a stop, and which is pinned down on the body of the pipe *d*. This mode of connexion leaves nothing further to be desired both in reference to strength and the facility with which it may be taken to pieces.

The inner pipe *f*, which, as we have already observed, rubs along the guides *i i*, is also in friction on the collar *m m'*, which can be tightened as it wears. The pipe *f* slides out and in, accordingly, as the tender leaves or approaches the engine. The bolts *h h'* serve to tighten the balls *a* and *b* as they are worn.

Care should be taken to grease all the surfaces in friction before starting. There is a great loss if the surfaces remain wet instead of being greased.

Figs. 97 and 98 give the elevation and plan of a new mode of connexion between the tender and the boiler, which is employed generally with the engines on the Saint Germains railway; loss of water which is so common by every other system is, on the contrary, very rare with the one we are about to describe, unless from neglect. It is composed of six conical joints, *a b c, a' b c'*. The pipes are formed of copper,

and enter one into the other, as shown in the section, (fig. 99.) The male-part is turned conical, and enters into the female-part, which is polished. These joints are protected by wrought-iron straps, as shown at *d*, with a pressure-screw on their upper parts; and they are attached with screw-bolts below K K, upon which they are able to turn. All the joints are made after the same manner, and permit of movements in every direction—viz., the three first, *a b c*, in the horizontal plane, and *a' b' c'* in the vertical. When the tender approaches the engine, the joints *a' b' c'* perform a slight rotation; the point E approaches the point D, the point T inclines towards C D; and the action is probably the same when the engine rises or lowers. The joints *a' b' c'* answer for all the horizontal movements; the joints *a b c* perform a slight rotation, which movements are continuous. These six joints partake of the same character as universal joints, in permitting movements in every direction; but the latter are disadvantageous in being dear, difficult to make, and to keep water tight. This new connexion is, therefore, more advantageous on every account. When the engine is required to be separated from its tender, the operation is very simple; the pressure screws are loosened, the straps turned upon the bolts K K, when the conical parts become separated from the pipes with which they were engaged. The part C D is situated near the engine, and *a b* next the tender. The arm C is in connexion with the platform occupied by the engine-driver, by which the lower horizontal part is sufficiently raised to be out of the way of all obstacles along the line. The cock *v* presents a communication between the pipes and the boiler for the feeding. The collars *m m'* serve to suspend the piping, which is effected partly by chains and partly by a spiral-spring, which neutralizes the shocks.

56. *On the Tender.* — The tender contains the water and coke, also all that is necessary for the engine-driver, both during the running and at the station. The general construction varies according to the maker, and does not offer

anything remarkable. There are two buffers *e e* behind the tender, corresponding to those of the carriages, (see fig. 89[2].) These buffers are furnished with an iron rod *b*, which passes the collar *c*, and is connected with a spring *r*, which receives the shocks. The ring *g*, which serves to attach the train, is secured by a rectangular iron piece *a*, through which the spring passes, this latter being fastened at the points *b b* to the buffer rods.

It is furnished with from four to six wheels, formed of cast-iron, in one piece, and enclosed with an iron-tire, with flanges, and is wedged upon the axles. The grease-boxes are similar to those of the engines. The springs are supported on the outer frame, (see fig. 89.) The guides of the grease-boxes are also fastened together by rods in the ordinary manner.

The reservoir for water is composed of plates of sheet-iron 1-5th of an inch in thickness, riveted together, and united at the angles by angle-irons: it is supported by iron brackets bolted to the frame. The upper part of the reservoir is covered with a box formed of sheet-iron, which is divided into four departments, intended to contain various things which are required by the driver of the engine, such as the oils, unguents, cloths, tow, &c. The water passes from this reservoir to the pipes of the pumps, through a small metallic cap, which is generally conical, and pierced with a great number of holes, but shut in on every side, which prevents any extraneous matter getting into the barrel of the pump.

The middle portion of the tender, below the reservoir, is filled with coke.

Fig. 100 (plate 59) gives a section of the water-tank of the tender. The level of the water is at *a b;* the section is similar on the other side of the tender. A cock, furnished with a vertical rod, A, permits the water to introduce itself into the pipe of the pump. The filterer *c* is indispensable, as the least impediment would prevent the play of the valves. The handle *m* is within the reach of the driver, and enables him to regulate the section of the supply of water to the pump.

57. *On the Break.*—The break is one of the most important contrivances connected with the tender, since it serves to moderate the speed of the engine. It operates on the wheels, by creating friction, which opposes the movement of the engine.

Fig. 101 (plate 60) shows one of the most simple breaks, which acts on one wheel only; it consists of a block of wood B, hollowed out to fit the outside of the wheel; it is fastened with an iron plate, and turns round a fixed point, near the frame of the tender. The lever L, with which the break is connected, produces the pressure on the wheel. The power of a lever, however, is neither sufficiently strong nor progressive in its action; the screw apparatus was, therefore, adopted, (see fig. 102.) It is evident, that the larger the segment of the wheel embraced, the more powerful will the break be.

The break acts in a more efficacious manner when it operates on two wheels; fig. 103 represents the most simple form of a double break. The lever turns the crank *m* round the fixed point A, which raises the block of wood and forces it against the wheels.

The break most frequently employed on the St. Germain's Railway is described in fig. 104. A pillow connected with the frame of the tender supports the fixed point B, upon which the balance *c c'* turns, which tightens the blocks on the wheels, by means of the rods *d' d'*. The pressure is regulated by shifting the position of the lever L on the stop-points of the bar B, which increases the length of the rods, by means of the screws *a a'*. A more simple form of the double break is shown in fig. 105 (plate 61); it presents greater simplicity in its construction, and is equally effective.

A system with wedges has also been employed, which is shown in fig. 106. The two uprights A A' turn round the two fixed points *b b'*, being moved by the two reversed wedges C D. This has the effect of either tightening or of untightening the breaks, and they are put into operation by the rod T, which is furnished with a screw. When the rod is

turned from right to left, it raises the wedges, and the wedge D acts upon the two bars *b b'*, which transmit the pressure to the wheels by means of the blocks *g g'*. When they turn from left to right, the wedges are lowered, and C loosens the breaks. It will be readily understood, that this tightening and untightening occurs simultaneously.

Stephenson has employed the check shown by fig. 107. The four points *a a'* are jointed. By raising or lowering the rod *t*, the breaks are tightened or untightened. This system presents every condition of strength and efficacy.

The break adopted by Hawthorn, (fig. 108, plate 62,) for the tender of his engine, is much more powerful than any of the preceding; but it requires to be used with great caution, to prevent rupture. The lever *b* turns round the fixed point and moves the balance, tightening the pieces of wood against the wheels, by means of the two rods *t t'*; so that, by bearing on *l*—*a a'* are tightened at the lower part, and *a'' a'''* tightened at the upper part. By lifting up the lever *l*, the action is reversed. The breaks do not act as long as the balance remains vertical, but they operate upon eight points when put in action, if these are applied on both sides. Their power is consequently very great.

The two breaks, whose views we again give, are applicable to carriages and wagons.

The break shown in fig. 109 is applied to two of the wheels; by raising up the fork *f*, the levers *l l'* turn upon their joint, assuming a horizontal position, and tighten the blocks on the wheels. When the fork is lowered, the levers are inclined, and the blocks separated from the wheels.

Fig. 110 is composed of a balance, *b*, the two ends of which are joined to two rods, *t t'*. When the breaksman rests on the handle at the end of the lever *l*, the lever *t* turns upon the fixed point *f*, and tightens the break on the wheel; the same movement, but reversed, is performed on the lever *t*, turning upon the fixed point *f'*.

We will conclude our remarks upon the tender, by pointing

out the methods employed in a great number of engines of heating the water of the tender. There are tubular straps on the feed-pipe, which receive the pipe employed in conveying the steam from the top of the boiler, and returning it to the reservoir by means of the pumps, when they are not feeding; also when there is an excess of steam in the boiler, which occurs at the time of stopping, and in passing down the planes. This steam is condensed in the reservoir, and thus heats the water. The cock of this pipe is under the control of the driver: he should open it when the engine stops, and the cocks of the feed-pumps also, which will assist the valves and economize the fuel.

58. *On the Application of the Expansion-Stop to Locomotive Engines.*—The expansion-stop may be advantageously applied to all engines, since the effective pressure on the piston is never so great as that in the boiler, or, at least, excepting certain obstacles are encountered. If it were necessary to maintain an effective pressure of four atmospheres during the running, it would be impossible to start the trains, since there would not be any disposable power to overcome the *vis inertia*. The economy of fuel is evident, from the following table:—

Fractions of the stroke during which the steam acts at full pressure.	Work produced by the application of the expansive stop in a cylinder, the work at full pressure being 1.	Work of the steam detained; the work of the same steam without the expansive stop being 1.
0·20	0·52	2·60
0·25	0·595	2·38
0·30	0·66	2·20
0·35	0·717	2·05
0·40	0·77	1·93
0·45	0·81	1·81
0·50	0·85	1·70
0·60	0·91	1·52
1·00	1·00	1·00

It will be seen, by this table, that by making the slide-stop of an engine equal to 3-10ths of the course, for example, we diminish the power of the engine about a third; but as the consumption of steam is diminished 7-10ths, it therefore results that the work produced by a certain amount of steam is more than doubled. The value of the stop is, therefore, very evident.

The shifting-stop which Mr. Edwards applied so happily to stationary engines some years ago, and which has produced such good results, was the first tried with locomotive engines.

Fig. 111 (plate 63) gives the general details of this arrangement. The slide outside the box *d*, communicating with the atmosphere, is furnished with two entrances *b*, *b'*, the size of which slightly exceeds one-half that of the ports of introduction.

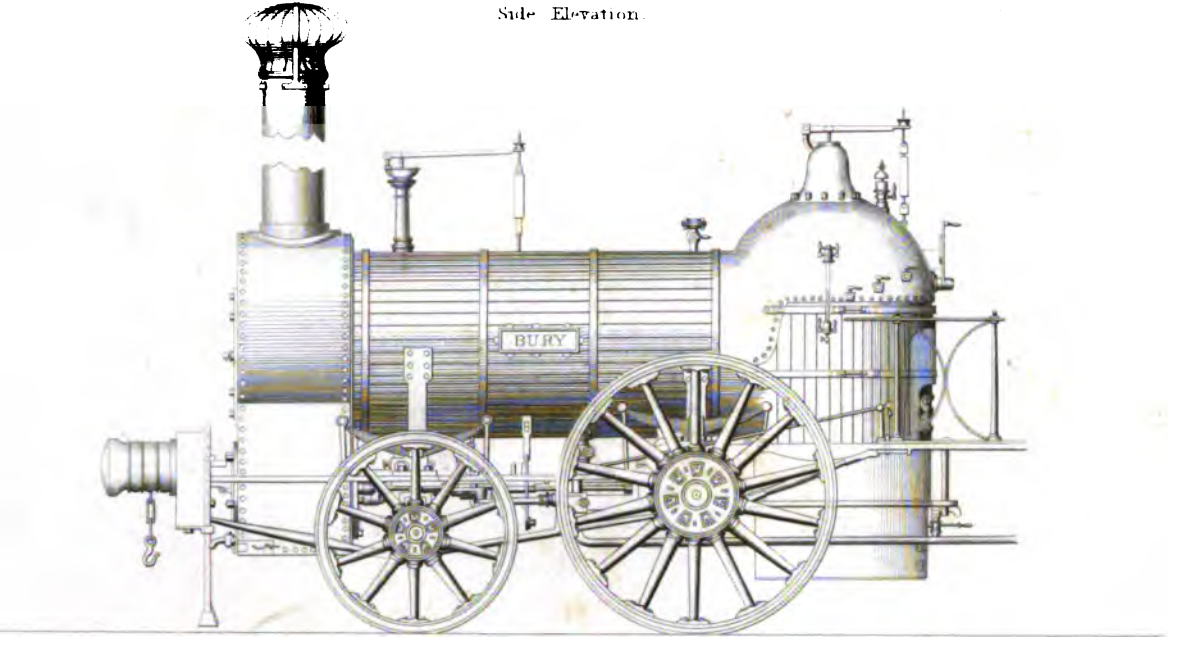
The slide complete is covered by a box *e*, which retains its place by gravity, and the action of the guide connected with the principal slide, which engages it in its movement.

When this cover is situated in the middle, the distribution is full and complete, the same as in other engines; if, on the contrary, the stops *a*, and *a'* are caught by the cover *e*, before the termination of the run of the slide, this inner cover closes the steam entrance; thus the stop *a* closes the entrance *b'*, and the stop *a'* closes the entrance *b*. It will be perceived that, by checking the two stops more or less, and always equally, the slide can be detained at any point of its course. The two stops are united by a rod, by which they always shut equally. They are regulated by a long rod, terminated by a screw, within reach of the engine-driver, who can thus diminish or increase the stop when he pleases.

APPENDIX.

EDWARD BURY'S LOCOMOTIVE ENGINE.

Side Elevation.



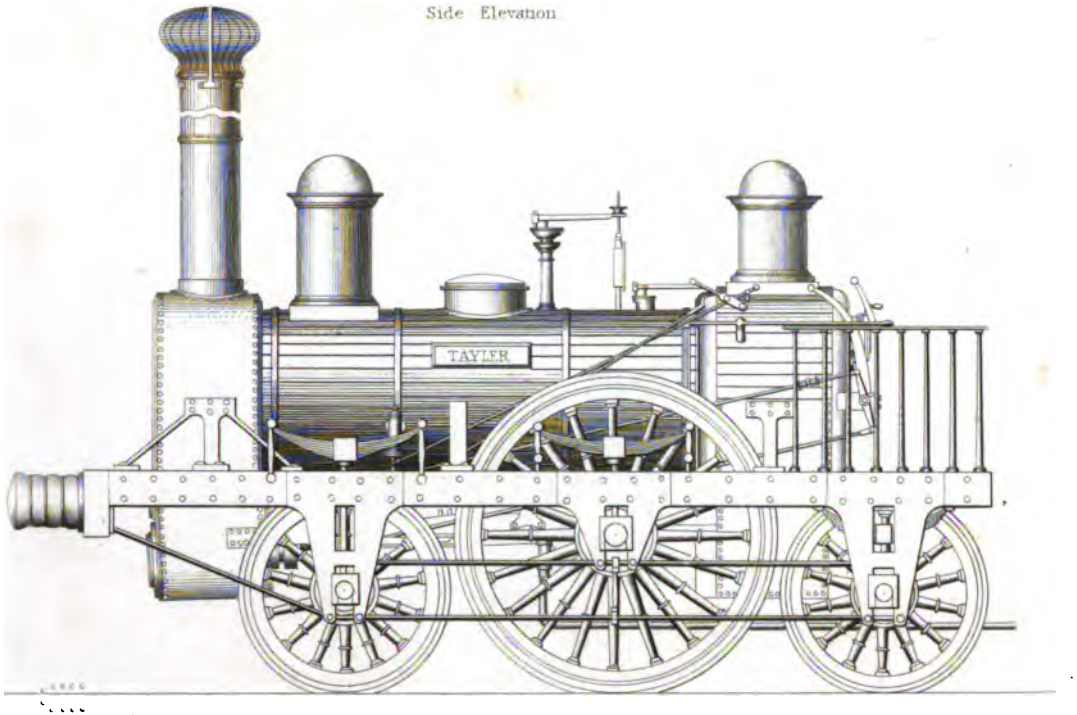
B.R.Davies fculp.

Plate I

NOT

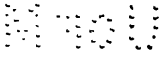
TAYLER'S LOCOMOTIVE ENGINE.

Side Elevation



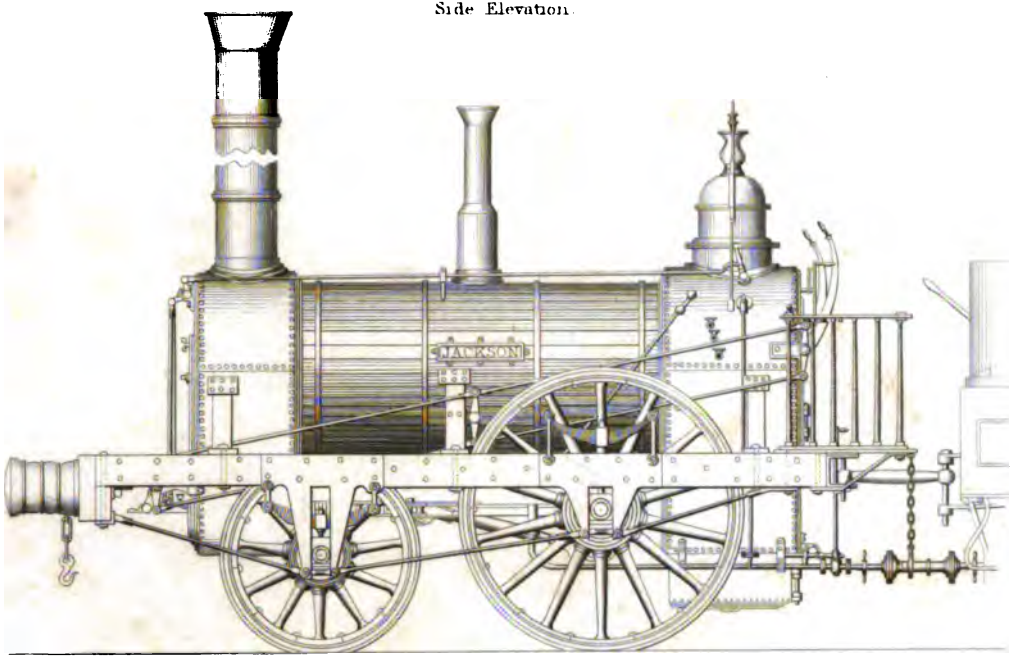
B. R. Davies, fculp.

Plate 2



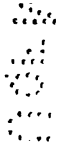
FENTON MURRAY & JACKSON'S LOCOMOTIVE ENGINE.

Side Elevation.



B R.Davies, sculp.

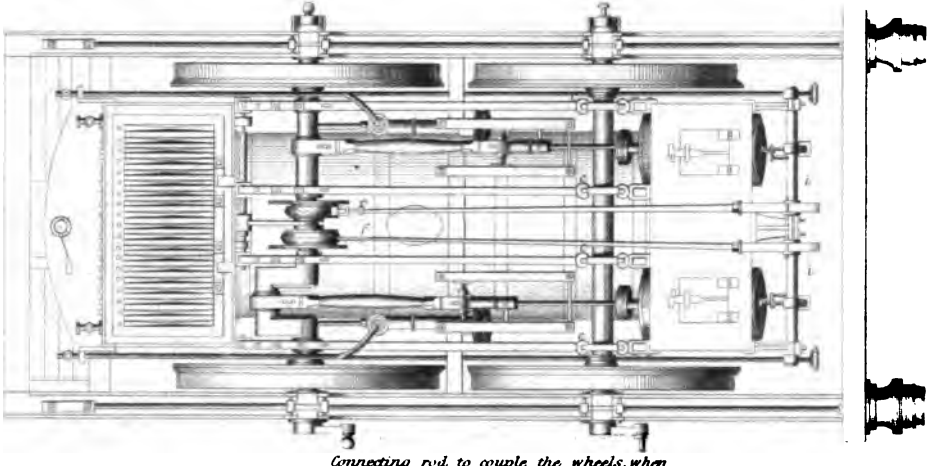
Plate 3.



JACKSON'S LOCOMOTIVE ENGINE HAVING FOUR WHEELS & TWO LOOSE ECCENTRICS.

Employed in conveying goods upon the St Etienne and Roanne Railway.

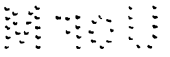
Plan of lower portion.



Connecting rod to couple the wheels when the engine conveys goods

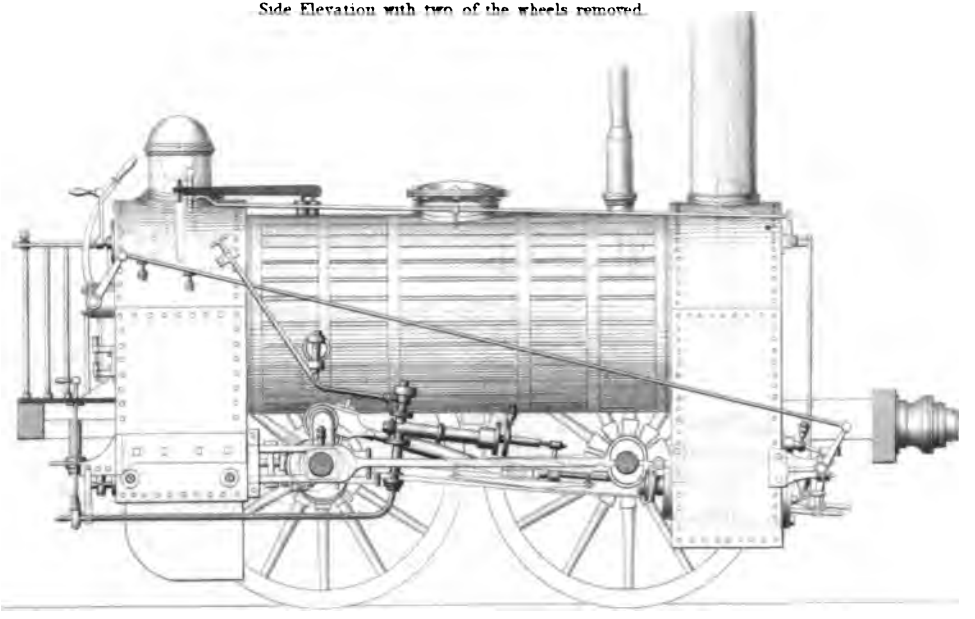
B.R.Davies. sculp.

Plate 4.



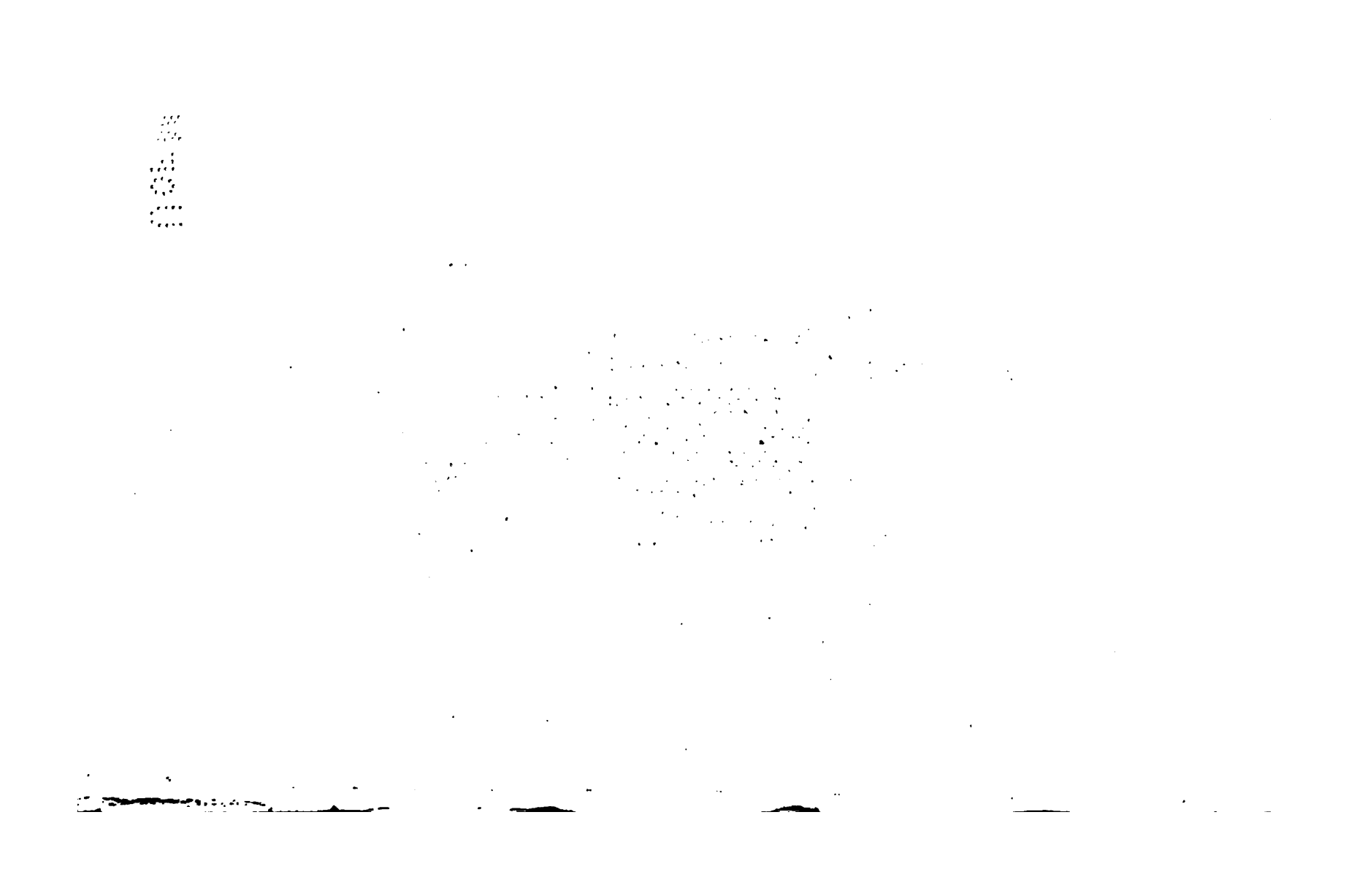
JACKSON'S LOCOMOTIVE ENGINE HAVING FOUR WHEELS & TWO LOOSE ECCENTRICS.

Side Elevation with two of the wheels removed.



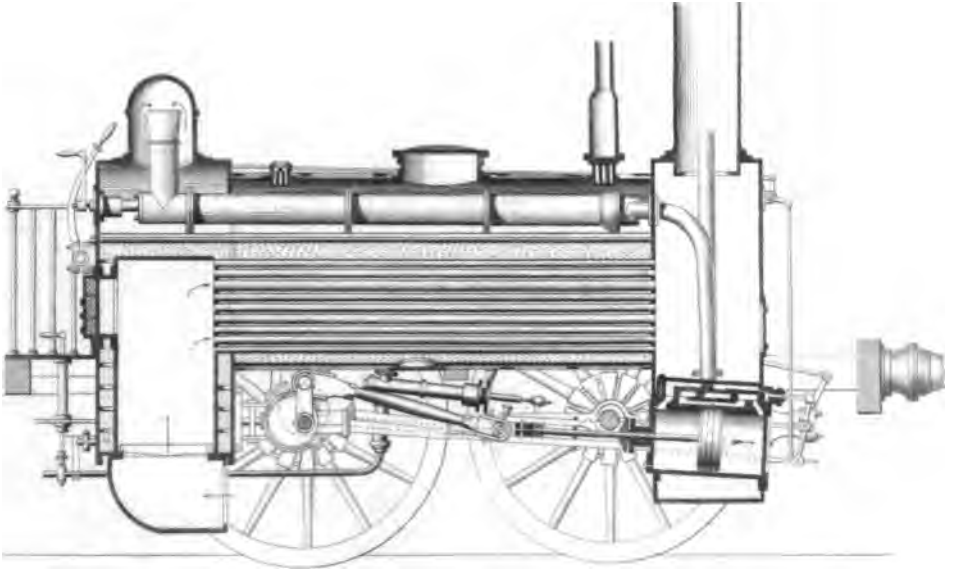
B.E.Davis sculp.

Plate 5



JACKSON'S LOCOMOTIVE ENGINE HAVING FOUR WHEELS & TWO LOOSE ECCENTRICS.

Longitudinal Section



B.R.Davies Sculp.

Plate 6.

FIRE BOX AND PORTION OF REGULATOR.

Fig. 2.
Section in the longitudinal direction of the boiler.

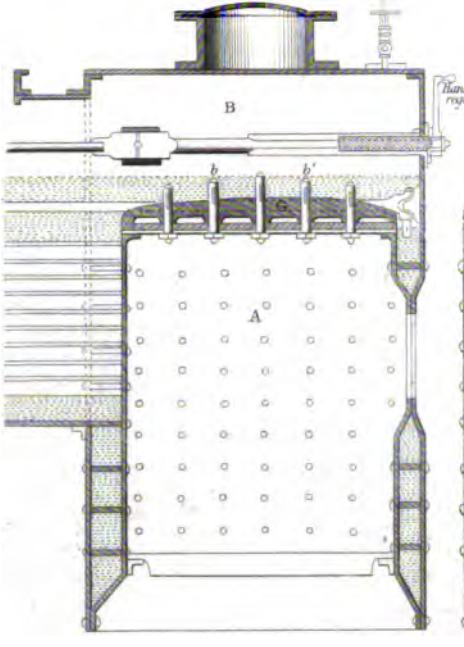


Fig. 1.
Section in the Transverse direction of the boiler.

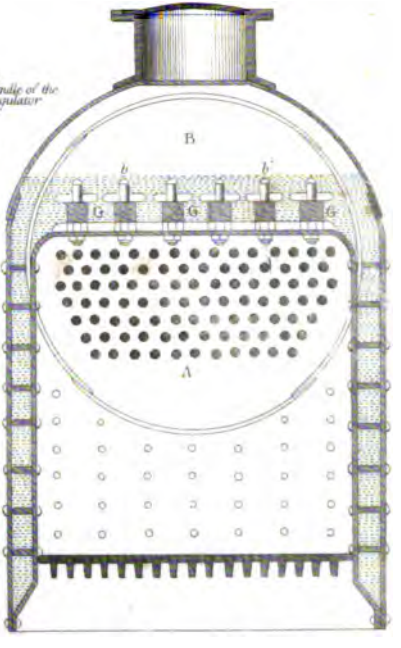
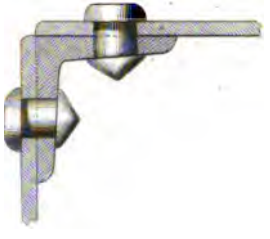


Fig. 4.
Section of a rivet of the iron plates.

Fig. 5.
Section of angle iron connecting the right angles.

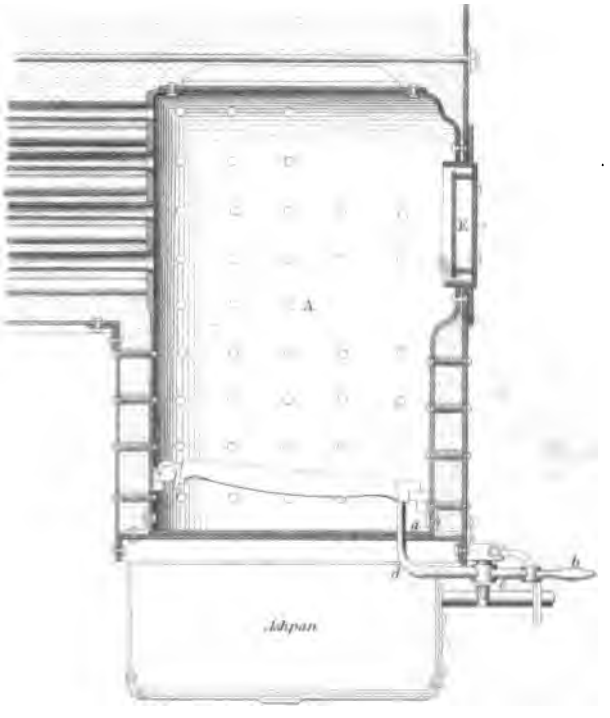


P.R. Davies, sculp.

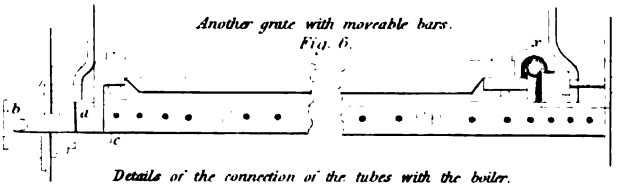
Plate 7.

Fig. 3.

Fire box with moveable grate bars of Jackson's locomotive (the smaller one)



Another grate with moveable bars.
Fig. 6.



Details of the connection of the tubes with the boiler.

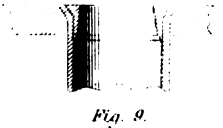
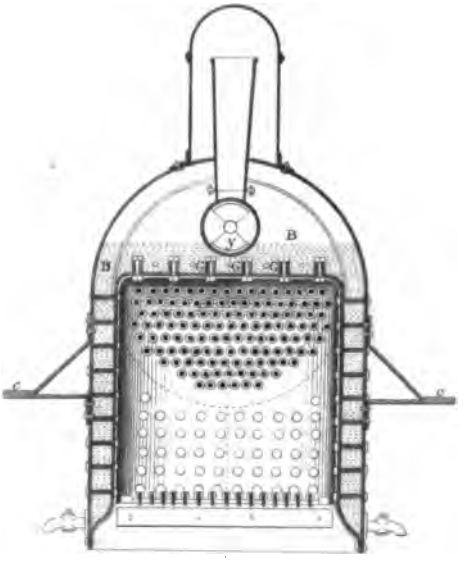


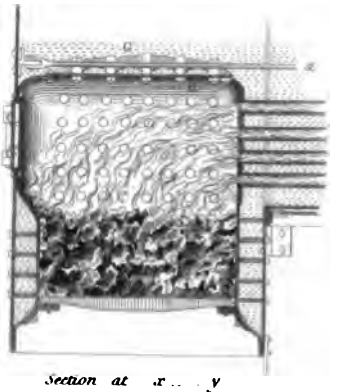
Fig. 9.

Fig. 8.

B R Davies fculp.

Fig. 7.
Stephenson's fire box.





Section at x . . y

LONDON

B R. Davies, sculp.

Fig. 10.

Stephenson's smoke box.

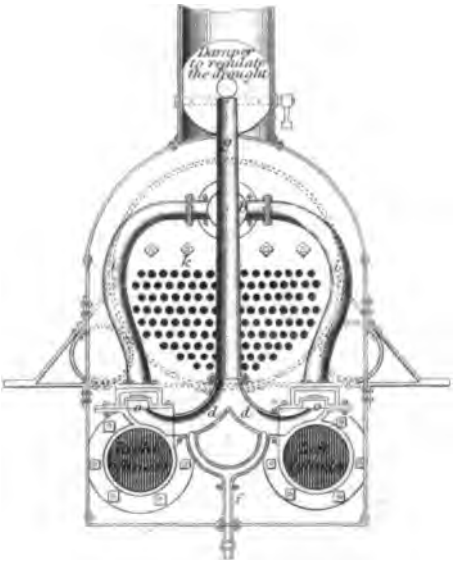
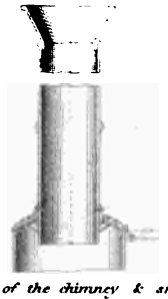


Fig. 11.

Smoke box with sloping cylinder.

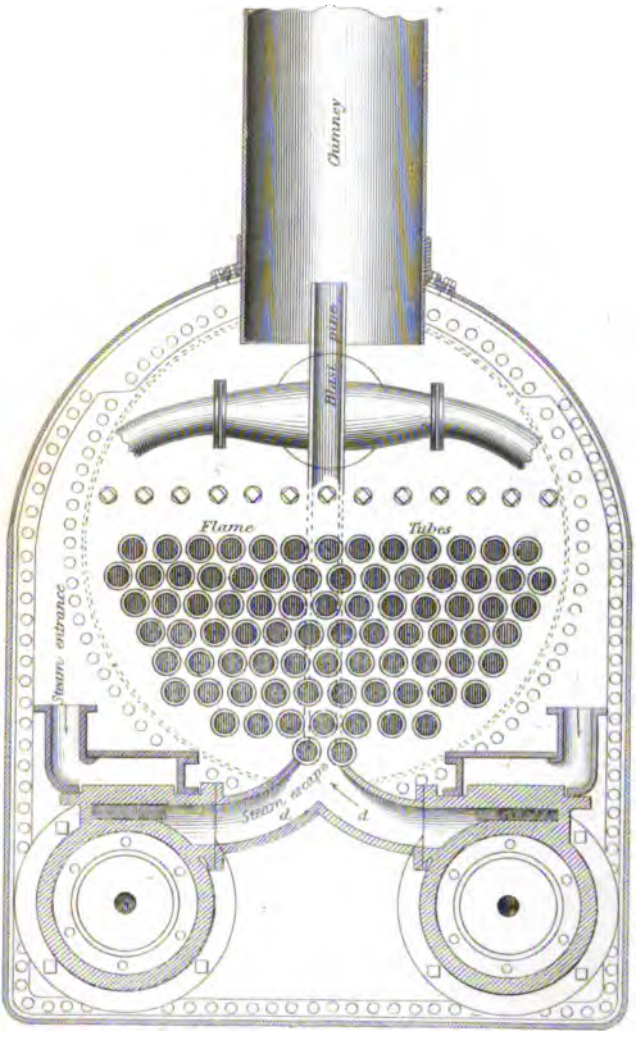
Fig. 12.



Joining of the chimney & smoke box.

B. R. Davies, fculp.

Fig. 13.
Smoke Box.



Front Elevation. &c.

Uorn

NOT FOR LOAN

A

FRENCH AND ENGLISH VOCABULARY

OF

TECHNICAL TERMS

Used in Engineering;

AND

A COMPARISON OF FRENCH AND ENGLISH WEIGHTS AND MEASURES.

Accouplé, *connected.*
Accouplées, *coupled.*
Acier, *steel.*
Adhérence, *adhesion.*
Aide, *assistant.*
Air chaud, *heated air.*
Alése, *polished, rounded, finished.*
Aller en arrière, *go backward* (*to*).
Aller en avant, *go forward* (*to*).
Alternatif, *reciprocating.*
Angle droit, *right angle.*
Anthracite, *Anthracite.*
Appareil, *apparatus.*
Appendices, *appendages.*
Argat, *canted.*
Arguille, *switch.*
Arbre, *spindle, shaft, or axle.*
Armature, bras, *arm.*
Armature du tiroir, *valve fittings.*
Arrête, *stop.*
Articular, *jointed.*
Articulation, *joint.*
Aspirer, raréfier, *suck* (*to*).
Asséchment, *drainage.*
Assemble à montaise, *morticed.*
Assist, *lift, stage.*
Atelier, *workshop.*
Attaché, callé, *fastened.*
Avance du tiroir, *lead of the slide.*
Axe, *axis.*
Axe goujon, *spindle.*
Axe coudé ou à manivelle, *cranked axle.*
Axe en T à deux leviers opposés, *cross axle.*

Baisseau, *bushel.*
Balance à ressort, *spring balance.*
Balancement, *balancing.*
Balancier, *beam.*
Balancier à vis, *screw-lever.*
Baleine, *moveable earthwork scaffold.*

Balancement de l'avant à l'arriere, *overbalancing.*
Balustrade, treillage, *fence.*
Banc, *stratum.*
Bandages des roues, *tires of the wheels.*
Bandes plates, *plate rails.*
Bandes fuillantes, *edge rails.*
Bandin, ou bourrelet, *flange.*
Banquette, *ledge upon the face of a slope.*
Barbelé, *spiked.*
Barrier, *fencing.*
Barres, *bars.*
Barres du foyer, *fire-bars.*
Barre plate, *flat bar.*
Barre ronde pliée, *bent rod.*
Bielle, *connecting-rod.*
Bloc de bois, calle, *block.*
Bois, *wood.*
Boîte, *box.*
Boîte à feu, *fire-box.*
Boîte à fumée, *smoke-box.*
Boîte à huile, *oil-cup.*
Boîte à vapeur, *steam-chest.*
Boîte des tiroirs, *slide-box.*
Boîte de roue, *chair of a wheel.*
Bombée, *rounded.*
Bome milliare, *milestone.*
Bouchon, *plug.*
Bouchon en plomb, *lead-plug.*
Boule, ou boulet, *ball.*
Boulon, *bolt.*
Boulonée, *bolted.*
Bras, armature, *arms.*
Bride, *strap, stirrup, lug, fillet.*
Bride de bascule, *tilting fillet.*
Bronze, *brass.*
Brouette, *barrow.*
Broncard, *shaft, or slide piece.*
Burin, ciseau, *chisel.*

Cadre, *frame.*
Cage, *frame, gate, groove.*
Cahir de charges, *specification.*
Caisse à fumée, *smoke-box.*
Calé, *wedge, or quoin, fasten (to).*
Calle attaché, *fastened.*
Calle, bloc du bois, *block.*
Calorique rayonnent, *radiating heat.*
Carryer, *forge iron, or hammer iron (to).*
Canaux, *canals.*
Cavilier, *earthen parapets.*
Cavité, entaille, *groove.*
Cendres, *cinders.*
Cendrier, *ash-pan.*
Centre, *centre.*
Cercle, *ring.*
Cercle, virole, *hoop.*
Chaine, *chain.*
Chaine sans fin, *endless chain.*
Charbon, *coal.*
Charbon de terre, houille, } *sea-coal.*
Chaleur, *heat.*
Chamber de vapeur, *steam-chest.*
Chambre de vapeur, *steam-room.*
Champon, *spike.*
Changement de voie, *changing place on railways.*
Chape, *guide-strap.*
Charge, *load.*
Charnières, *hinges.*
Charpentier, *carpenter.*
Chassis, cadre, *frame.*
Chassis exterieur, *outside frame.*
Chassis interieur, traverses, } *inside frame.*

Chaude, *heats.*
Chaudière, *boiler.*
Chauffe, *furnace.*
Chauffeur, *fire-man.*
Chaussée, *road.*
Chautier, *a gullet, or single working in earthwork; also a yard.*
Chemin de fer, *railway.*
Chemin, voie, *way, or line.*
Cheminée, *chimney.*
Cheville, *iron pin.*
Chevillette, *spike.*
Chock, *jerk, shock.*
Ciseau, burin, *chisel.*
Clapet, tiroirs, soupapes } *valves.*
Clavette et contre clavette, *gib and cottar.*
Clavette, *pin.*
Clef, *key.*
Clés de calage, *tightening and wedging keys.*
Cloture, *fencing.*
Cloures, *closing or jointing.*
Clouteric, *spikes.*
Coin, *wedge.*
Coin de serrage, *tightening wedge.*
Collet, *collar.*
Collier, *collar.*
Coltenage, *conveying.*
Combustible, *fuel.*
Couche, *lift in earthwork.*
Condé, *bent or cranked.*
Condensation, etat d'aggrégation de la vapeur, ramenée à l'état liquide. } *condensation.*
Conducteur moteur, *driver.*
Conducteur de convoi, *guard.*
Conducteur de machine, *engine-man, or driver.*
Conduit d'echappement, *blast-pipe.*
Conduit en entonnoir, *funnel-pipe.*
Conduit de distribution, *pipe of distribution.*
Conique, *conical.*
Constructeur, *builder.*
Contre-rails, *guard-rails.*
Contre-poids, *counterpoise.*
Cornière, *angle-iron.*
Corps de pompe, *barrel of a pump.*
Coton, mèche de coton, *cotton.*
Couler, *cast or melt (to).*
Coupe, *section.*
Course, *alternation,* ("deux courses," *make one stroke.*)
Coude, *crank.*
Coup de piston, *stroke of the piston.*
Coup d'arrière, *back stroke.*
Coup d'avant, *fore stroke.*
Counterfort, *counterfort, shoulder.*
Courbe, *curve.*
Coussinet, voiture, *carriage.*
Coussinet de boite à graisse, *carriage or grease-box; gland, bush, pillow.*
Couvercle d'un cylindre, *cylinder cover.*
Crámaillères, *rack.*
Crapaudine, palier, *fulcrum.*
Crapaudine, *socket.*
Crau, *notch.*
Crin, *horse-hair.*
Crochet, *hook.*
Crochet d'attelage, *draw-link.*
Croisement, *crossing.*
Cube, *cubic.*
Cuir, *leather.*

Cuivre, *copper.*
Cuisière d'une balance, *index of a balance.*
Cylindre, *cylinder.*
Cylindre d'egrossisseur, *drawing cylinder.*

Dame, *rammer.*
Dé en pierre, *stone block.*
Déblais, tranchée, *filling, cutting.*
De champs, *edgeways.*
Déchat, *wear and tear.*
Degrès, *degrees.*
Dent d'un roue, *cog (of a wheel).*
Descente, *descent.*
Désembrayer, *disengage.*
Désengrénées, Débrayes, } *disengaged.*
Desséchement, *draining.*
Dés, *block.*
Détente, *trigger or stop (applied to the expansion-stop).*
Diamètre, *diameter.*
Diamétre extérieur, *diameter outside.*
Diamétre intérieur, *diameter inside.*
Dimension, superficie, *size.*
Double-fonds, *double casing.*
Doublure, *lining.*
Dynanometre, Mesure de force, } *dynanometer.*
Douille, *socket.*

Eau, *water.*
Éboulement, *slip.*
Écartement des points d'appui, *bearing.*
Échafaud, *scaffold for discharging earth.*
Echalat, *stay.*
Echappement, perte, *escape.*
Echappement de vapeur, *puff, or steam-puff.*
Échelle, *scale.*
Echelle graduée, *graduated scale.*
Écrou, *nut, or nut-box of a nut, or female screw.*
Effort, choc avec frottement, *strain.*
Égal, *equal.*
Égout, *sewer or drain; also the eaves of a house.*
Elasticité, *elasticity.*
Embrayer, *engage (to).*
Emboutissage, *riveting.*
Emission, *eduction.*
Emmanchement, *joint.*
Emprunt, *a side-cutting.*
En arrière, *backwards.*
En avant, *forwards.*
En régie, *by valuation.*
Encardrement, *framing or curbing.*
Enclauché, *placed or connected.*
Enclume, *anvil.*
Encoche, *notch.*
Encoche, œil, *eye.*
Engrenages, roues dentées, *cog-wheels.*
Entaille, *notch.*
Entaille, cavité, trou, *groove.*
Entraine, *engage (to).*
Entreprenneur, *contractor.*
Entretoise, *tie-bolt.*
Équerre, *square.*
Equerre en fer, *iron knee.*
Escalier, *staircase.*
Espace, *space.*
Essieu, *axle or axletree.*

Essieu coude, *cranked axle.*
Étanche, contenant l'eau, *water-tight.*
Étanche de vapeur, contenant la vapeur, *steam-tight.*
Éteindre, *extinguish (to).*
Étoupe, *hemp.*
Etançon, *shore, stay, or stop.*
Etais, *stays.*
Etriers, *stirrups.*
Excentrique, *eccentric.*
Expérience, *experiment.*

Fascines, ou bouveaux, *fascines, cradles.*
Fer, *iron.*
Fer brut, *coarse iron.*
Fer de font, *cast iron.*
Fer ou forgé, *wrought iron.*
Fer martelé, *hammered iron.*
Fer liminé, *rolled iron.*
Fer ballés, *bar iron.*
Fer-méplat, *flat-iron.*
Fermé, *shut.*
Frottement, *friction.*
Ferrules, *iron work.*
Feu, *fire.*
Feuilles, *sheets or leaves.*
Filet d'une vis, *flame.*
Flamme, *flame.*
Fléche, *arrow.*
Fond, *bottom.*
Fonte, *cast iron.*
Force accélératrice, *accelerating force.*
Force élastique, tension, *elastic force.*
Forgeron, *smith.*
Fossé d'écoulement, *drain.*
Fossés, *ditch.*
Fouille et charge, *getting and boarding.*
Fourche, *fork.*
Fonte, *cast metal or brass.*
Fraisé, *countersunk, plait, rose.*
Fraisement, *starling.*
Frein, *break.*
Frette, *tire of a wheel, frame, ferrule.*
Fusée, *gudgeon.*

Gabarit, *gauge.*
Galerie, *footboard.*
Galet, *friction roller.*
Garde-crotte, *splasher.*
Gare, *station.*
Gargouille, *small drain.*
Garniture de voite d'etoupe, *packing.*
Gaz, *gas.*
Glissoires, tiroirs, *slides.*
Gootet, *cup.*
Goujon central, *centre pin.*
Goujon, *gudgeon, pin.*
Goupille, *pin.*
Gouttière, *gutter or trough.*
Grandes traverses, supports du poids, } *weigh-bars.*
Grillage, *grating.*
Grille du foyer, *fire-grate.*
Girdres glissoires, *girders.*
Griffe, *claws.*
Grue, *crane.*

Hangar, *shed.*
Heure, *hour.*
Helix, *spiral.*
Hommes qui agissent sur les freins, *breakmen.*

Houille, charbon de terre, *sea-coal.*
Huile, *oil.*

Indemnité, *compensation.*
Ingénieur, *engineer.*
Interieur, *inside.*

Jantes de roues, *rims* (*of wheels.*)
Jet, jalissement, *jet.*
Jet de melange d'eau et de vapeur, *priming.*
Joints à boule, *universal joints.*

Lame, *edge.*
Laminage, *rolling.*
Langrine, *sleeper.*
Largeur, *width.*
L'eau entrainée, *priming.*
Levier, *lever.*
Levier de reversement de la distribution ou leviers de déchachment, *reversing, or hand-gear.*
Ligne, *line.*
Ligne droit, *right line.*
Livres Anglaises, *pounds avoidupois.*
Livre, *pound, lb.*
Longueur du coup *ou* course, *length of stroke.*
Longuerines, *longitudinal beams.*
Loquets à ressort, *spring-latch.*
Lumières, *steam-ports.*
Lumière d'introduction, *port of introduction.*
Lumière d'echappement, *port of escapement.*

Machine, *engine, or machine.*
Machine à planer, *planing machine.*
Machines fixés, *stationary engines.*
Machines à quatre roues, *four-wheeled engines.*
Machines à six roues, *six-wheeled engines.*
Machine à vapeur, *steam engine.*
Machine locomotif, *locomotive engines.*
Madrier, *a thick plank.*
Manchon, *collar, muff.*
Manette, *handle.*
Manivelle, *crank, or crank-arm.*
Manometre à mercure, *mercurial gauge.*
Manton, *rammer.*
Montant, *upright piece, stile, or joint.*
Marchandize, *goods.*
Marche d'escalier, *step* (*of a staircase*).
Marche en arrière, *retrograde motion*
Marche en avant, *forward motion.*
Marteau-pilon, *tilt hammer.*
Materiaux, *materials.*
Mecanisme, *mechanism.*
Mèche à siphon, *syphon-wick.*
Mèche de coton, *cotton-wick.*
Membrures, *stiles, rails, or framing.*
Mecanicier conducteur de machine, *engine man.*
Mésure du niveau de l'eau, *water-gauge.*
Mille (1609 metres), *mile.*
Minutes, *minutes.*
Mi-plat, *bar-iron.*
Miter oblituration conique, *mitre.*
Moteur conducteur, *driver.*
Mouvement, travail, *work.*
Mouvement alternatif, *alternate motion.*
Moyeau, *nave.*

Nervures, *mouldings.*
Niveau, *level.*
Nivelete, *a level.*
Noyée, *let in, countersunk.*

Orielle, *legs, earpiece, cheek, socket.*
Orifice de nettoument, *mud holes.*
Ouverture, rainure, *opening, aperture.*
Ouverture d'un arche, *span.*
Ouverture, ou conduit de vapeur, *steam-port.*

Palier, support-crapaudine, *fulcrum, standard.*
Palier, *pillow, or bracket, also the landing of a staircase.*
Parcours d'une ligne de chemin de fer par un convoie, *trip.*
Paroi, *casing, side.*
Partie frottement, *part in friction.*
Passageur, voyageur, *traveller.*
Passage de neveau, *level crossing.*
Pautre, *beam, girder.*
Pelle, *spade.*
Pesage, *weight.*
Pesanteur, gravity.
Peute, *fall, or falling gradient.*
Piece à culotte, tuyau bifurque, *breeches-piece.*
Pièce croisse, *cross-piece.*
Pied, *foot.*
Pied carré, *square-foot.*
Pied cube, *cubic foot.*
Pierre, *stone.*
Pierre de taille, *curb-stone.*
Pignet, *picket.*
Pignion, *pinion.*
Pilot, *pile.*
Pince en fer, *crow-bar.*
Pioche, *pick-axe, mattock.*
Piston, *piston.*
Pivot à crapaudine, *socket.*
Pivot, *pivot.*
Plan incliné, *inclined plane.*
Plan automoteur, *self-acting plane.*
Plancher, *supporting plank.*
Plat-band, *fillet.*
Plateau, *platform.*
Plaqué tournante, *turn-plate.*
Plaque, *plate.*
Plomb, *lead.*
Plongement, action des machines de plongeur sur les rails, *pitching, jumping.*
Plongeur, *plunger.*
Poids, *momentum.*
Pompe, *pump.*
Pompe alimentaire, *feed pump.*
Pompe aspirante, *suction pump.*
Pompe foulante, *forcing-pump.*
Ponceau, *culvert.*
Pont, *bridge.*
Port à faux, *false bearing.*
Porte, *door.*
Portes de la boîte a fumée, *smoke-box doors.*
Pose et entrétien, *laying and maintaining.*
Poseur, *plate layer.*
Pouce, *inch.*
Poulies, *pulleys.*
Pression, *pressure.*
Prise de vapeur, *steam entrance, or entrance pipe.*
Prix de revient, *cost price.*
Puissance calorifique, *heating power.*
Puissance d'evaporation, *evaporating power.*

Puissance en chevaux, *horse power.*
Puisard au puits absorbents, *absorbing, or dry well.*

Quadrante, quatre de cironférence, *quadrant.*
Quantité, *quantity.*
Quarré, *square.*
Quintal, *cwt.*
Queue d'aronde ou d'hirondelle, *joggle, dove-tailed tenon.*

Raide, *stiff.*
Raies (d'un roue), *spokes.*
Raies creuses, *tubular spokes.*
Rail à champignon, *the* T *edge rail.*
Rails-evidée, *bridge-rails.*
Rails-undulés, *fish-bellied rails.*
Rainure, *groove.*
Rainure et longuette, *plough and tongue.*
Rampe, *fall, or falling gradient.*
Rangée, *row.*
Ranchat, *pin.*
Rayon, *radius.*
Rayon de courbe, *radius of curvature.*
Rebord, *flange.*
Rebord des bandages des roues, *flange of the tires.*
Recouvrement du tiroir sur les lumières, *overlap.*
Régalage, *levelling* (*in earthwork*)
Registre, *damper.*
Regles, *rules.*
Regulateur, robinet d'entrée de vapeur, *regulator.*
Regulateur de vapeur, *steam regulator.*
Remainement, *leading and discharging* (*in earthwork.*)
Remblai, *embankment, filling.*
Remise, *shed.*
Remonte, *ascent.*
Renflement central, *centre boss.*
Reparation, *repair.*
Résistance, *resistance.*
Ressorts, *springs.*
Réunion, *connexion.*
Riblous, *scrap-iron.*
Rigole, *drain.*
Rivé, *riveted.*
Rivets, *rivets.*
Robinet, *cock.*
Robinet à deux eaux, *two-way cock.*
Robinet d'essai des pompes (petit robinet), *pet, or trial cock.*
Robinet dessai ou de vidange avec pression de vapeur, *blow-off cock.*
Robinet pour mésurer le niveau, *gauge-cock.*
Roucouvrement, *overlap.*
Roudelle, *washer.*
Roues, *wheels.*
Roues accouplés, *wheels coupled.*
Roues dentées engrenager, *cog-wheels.*
Rouleau, *roller, cylinder.*
Route, *road.*

Sable, *ballast.*
Saillées, *projections, cheeks.*
Salaire, *wages.*
Samelle, *flat foot.*
Sapin, *fir, or pine wood.*
Scellement, *fastening.*
Scie, *saw.*
Sediment, incrustation dépôts, *sediment.*
Segmens, parties d'un cercle, *segments.*

Siège de la soupape, *seat of the valve.*
Sifflet, *whistle.*
Siphon, *syphon.*
Socle, crapaudine, *socket.*
Soudé, *welded, soldered.*
Soupapes tirois, clapets, *valves.*
Soupapes de sûreté, *safety-valves.*
Soupapes fixé, *lock up safety-valve.*
Soupapes variable, *ordinary safety-valve.*
Soutemain, *tunnel.*
Station pour alimentation de l'eau, *watering station.*
Suif, *tallow.*
Support, *pillar.*
Surface, *area.*

Tache, *task-work.*
Taillant côté de champ, angle, *edge.*
Taillé en chamfrein, *chamfered.*
Talus, *slope of a bank.*
Tampon, *buffer.*
Taraud, *screw, tap, or tapped.*
Tarier, *auger.*
Tacquet, *cleat, or peg.*
Tasseaux, *brackets, or supports.*
Terrassement, *earthwork.*
Terrassier, *navigator.*
Tête d'une tige, *head of a rod.*
Têtes croisées, têtes de bielle ou de tige, *cross-heads.*
Tige des tiroirs, *slide-rods.*
Tige du piston, *piston-rod.*
Tige à levier, *lever-rod.*
Tirage, *draught.*
Tirans, *ribs.*
Tirans ou barres d'excentrique, *eccentric rods.*
Tiraut, *bolt, or holdfast.*
Tissu d'en chauvre, *hemp cloth.*
Tiroirs glissoires ou coquille, *slides.*
Toîle, *canvass.*
Tole, *sheet, or plate iron.*
Tôle fer en feuilles, *wrought plates, sheet iron.*
Tombereaux, *carts.*
Tonne (100 k), *ton.*
Tourillon, *turning piece, gudgeon, pivot.*
Traction, *haulage.*
Train poids remoyné, *train.*
Tranchée, deblais, *cutting.*
Tringle, *rod.*
Trottoir, *platform.*
Traverse, *sleeper, cross-sleeper, or iron, &c.*
Treillage, *paling, or hurdle.*
Trou, cavité, entaille, *groove.*
Trou d'homme, *man-hole.*
Tube, *tube.*
Tube de verre, *glass-tube.*
Tuyau ou conduit, *pipe.*
Tuyau à vapeur, *steam-pipe.*
Tuyau biferque, *breeches piece.*
Tuyau d'aspiration, *suction-pipe.*
Tuyau d'echappement de vapeur, *blast-pipe.*
Tuyau d'embranchement, *branching-pipe.*
Tuyau de sortie, *delivery-pipe.*
Travail, mouvement, *work.*
Travailleurs ou roues metrices, *driving-wheels.*

Usure, *wear.*
Usine, *works.*
Voie d'évitement, *siding-place.*
Vanne, *hatch, flood or water-gate.*

Vapeur, *steam.*
Vaz et vient ou mouvement alternatif, *alternating movement.*
Venteaux, *gates.*
Verge, *rod.*
Verre, *glass.*
Virole, *ferrule.*
Vis, *screw, or he-screw.*
Vissé, *screwed.*
Vis de pression, *force-screw.*
Vis de serrage, *tightening-screw.*
Vitesse, *velocity, speed.*
Voie, *way or line of rails.*
Voie définitif, *permanent way.*
Voie provisoire, *temporary way.*
Voies de changement et de changemens dans les stations, *sidings.*
Voiture, *carriage.*
Volant, *fly-wheel.*
Voyage, *trip.*
Voyageur, *passenger.*

COMPARISON OF FRENCH AND ENGLISH MEASURES AND WEIGHTS.

THE MODERN SYSTEM—(DECIMAL).

MEASURE OF LENGTH.

	French Metres.		English Yards.		Imperial Inches.
Milli-metre	·001	—	or ·0010936	—	or ·039371
Centi-metre	·01	—	·010936	—	·39371
Deci-metre	·1	—	·10936	—	3·9371
METRE	1·	—	1·0936	—	39·371
Deca-metre	10·	—	10·936	—	393·71
Hecto-metre	100·	—	109·36	—	3937·1
Kilo-metre	1000·	—	1093·6	—	39371·
Myria-metre	10000·	—	10936·	—	393710·

The Metre, or unit of length, is the ten millionth part of the terrestrial arc (from the equator to the pole).

One Metre is equal to 1·0936 yards, or 3·2809 feet, or 30·371 inches.

One Myria-metre is equal to 6 miles, 1 furlong, 28 poles, and $2\frac{1}{3}$ yards.

NOTE.—The Deci-metre, Centi-metre, and Milli-metre are respectively formed by dividing the metre by 10, 100, 1000, and the Deca-metre, Hecto-metre, Kilo-metre, Myria-metre by multiplying the metre by 10, 100, 1000, and 10,000. The other measures and weights of the decimal system are formed in the same manner from their respective units.

MEASURE OF SURFACE.

Milli-are ..... 155· square inches.
Centi-are ..... 10·764 square feet.
Deci-are ..... 11·96 square yards.
ARE ..... 119·6 „ „
Deca-are ..... 1196· „ „
Hect-are ..... 2·472 acres.

The Are, or unit of square measure, is equal to = 1 square deca-metre.

MEASURE OF SOLIDITY.

Milli-stere ..... 61·028 cubic inches.
Centi-stere ..... 610·28 „ „
Deci-stere ..... 3·5317 cubic feet.
STERE ..... 35·317 „ „
Deca-stere ..... 13·08 cubic yards.
Hecto-stere ..... 130·8 „ „
Kilo-stere ..... 1308· „ „

The Stere, or unit of solid measure, is equal to = 1 cubic metre.

MEASURE OF CAPACITY.

Milli-litre ..... ·061028 cubic inches.
Centi-litre ..... ·61028 „ „
Deci-litre ..... 6·1028 „ „
LITRE ..... 61·028 or 1·761 imperial pints.
Deca-litre ..... 2·2 imperial gallons.
Hecto-litre ..... 2·75 imperial bushels.
Kilo-litre ..... 35·317 cubic feet.
Myria-litre ..... 353·17 „ „

The Litre, or unit of measure for liquids, is equal to = 1 cubic deci-metre.

MEASURE OF WEIGHT.

Milli-gramme..... ·015434 grains troy.
Centi-gramme ..... ·15434 „ „
Deci-gramme ..... 1·5434 „ „
GRAMME..... 15.434 „ „
Deca-gramme ..... ·32154 oz. troy.
Hecto-gramme ..... 3·2154 „ „ or 3·527 oz. avoird.
Kilo-gramme..... 2·6795 lbs. troy, or 2·2048 lbs. avoird.
Myria-gramme... 26·795 „ „ or 22·048 „ „

The Gramme, or unit of weight, is equal to = 1 cubic centi-metre of distilled water *in vacuo* at its maximum density, or 39° Fahrenheit.

The French quintal equals ..... 1 cwt. 3 qrs. 24½ lbs.
The French millier or bar, 9 tons, 18 „ 3 „ 12 „

THE OLD FRENCH SYSTEM—(SYSTEM USUEL.)

MEASURE OF LENGTH.

Ligne..... 0·091 inches English.
Pouce = 12 Lignes ..... 1·093 „ „
Pied = 12 Pouces..... 13·12 „ „
Aune = 3⅝ Pieds..... 3·937 feet English.
Toise = 6 Aunes ..... 6·562 „ „

The Aune is equal to = 12 decimetres.
The Toise is equal to = 2 metres.
One Post League is equal to = 4263 yards (English).

MEASURE OF CAPACITY.

Litron ... 1·376 imperial pints (English).
Baisseau... 2·7515 „ „ or nearly 1⅜ imp. pecks (English).

MEASURE OF WEIGHT.

Grain		·837 grains.
Gros	= 72 grains	60·285 „
Once	= 8 gros	1·1024 oz. avoird.
Livre	= 16 onces	1·1024 lbs. avoird.

The Livre is equal to = 500 grammes.

COMPARISON OF ENGLISH AND FRENCH MEASURES AND WEIGHTS.

MEASURE OF LENGTH.

Inch..... 2·539 centi-metres.
Foot = 12 inches ..... 3·0479 deci-metres.
Yard = 3 feet ..... 0·91438 metres.
Mile = 1760 yards,..... 1609·31 metres.

MEASURE OF SURFACE.

Square inch ..... 6·444 square centi-metres.
Square foot = 144 sq. ins. ..... 9·2903 square deci-metres.
Square yard = 9 sq. feet ..... 0·83697 square metres.

MEASURE OF CAPACITY.

Cubic inch ..... 16·3052 cubic centi-metres.
Cubic foot = 1728 cub. ins. ... 28·314 cubic deci-metres.
Cubic yard = 27 cub. ft. ... 764·58 „ „
Pint ..... ·55 „ „
Gallon = 8 pints ..... 4·404 „ „
Bushel ..... 35·238 „ „

MEASURE OF WEIGHT (AVOIRDUPOIS).

Once		28·338 grammes.
Libra (lb.)	= 16 oz.	453· „
Cwt.	= 112 lbs.	50·796 kilogrammes.
Ton	= 20 cwt.	1015·938 „

The French bring everything to the decimal standard; thus, a railway grade is described either as a "rise" or "fall" of so many milli-metres or centi-metres, meaning so many milli-metres or centi-metres per metre:—thus,

A grade	of	4 milli-metres	per	metre	is	1 in 250.
„	„	5 milli-metres	„	„		1 in 200.
„	„	7 milli-metres	„	„		1 in 143.
„	„	11 milli-metres	„	„		1 in 90.
„	„	14 milli-metres	„	„		1 in 70.
„	„	15 milli-metres	„	„		1 in 67.
„	„	4 centi-metres	„	„		1 in 25.
„	„	5 centi-metres	„	„		1 in 20.
„	„	14 centi-metres	„	„		1 in 7.

892)